



Arnold Schwarzenegger
Governor

FOUNDARY ENERGY CONSERVATION MANUAL

VOLUME II - Workbook, 1981

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Public Interest Energy Research Program

Prepared By:

California Cast Metals Association

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FOUNDRY ENERGY CONSERVATION MANUAL

Volume II - Workbook

1981

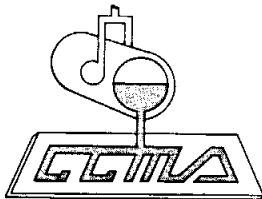


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VOLUME II

ENERGY MANAGEMENT WORK BOOK

TABLE OF CONTENTS

SECTION I

INTRODUCTION

PART A

EXHIBIT NO.

ENERGY USE TABLES AND PRODUCTION STATISTICS

Electrical Power Usage	Table 1
Annual Gas Consumption	Table 2
Annual Coke Consumption	Table 3
Annual Oil Consumption	Table 4
Annual Propane Consumption	Table 5
Annual Production	Table 6
Plant Equipment Horsepower List	Table 7
Flow Rates of Gas Fired Equipment	Table 8
Present Energy-Efficiency Record	Table 9
Potential Energy-Efficiency Record	Table 10

PART B

OPERATIONAL DATA FACT SHEETS

7-day Electrical Load Profile Form	Figure 1
48-hour Electric Load Profile Form	Figure 2
Electric Arc Furnace Data	Table 1
Coreless Induction Furnace Data	Table 2
Gas Melt Furnace Data	Table 3
Heat Treat Furnace Data	Table 4
Burn-Out Furnace Data	Table 5
Ladle Preheat Data	Table 6
Cupola Furnace Data	Table 7
Electric Heat Treat Furnace Data	Table 8
Gas-Fired Scrap Preheat Data	Table 9

SECTION II

Page

INTRODUCTION

A. ELECTRIC MELTING

General	A-1
Input data	A-1
Load profile development	A-5
Off-peak melting	A-6
Demand shifting and demand control	A-9
Demand control	A-13
Power factor correction	A-14
Improved furnace design	A-14
Summary - potential energy savings	A-16

B. NATURAL GAS MELTING

General considerations	B-1
Gas furnace data input	B-2
Tables, graphs, and charts	B-3
Sample calculations (crucible furnaces)	
• Improving combustion efficiency	B-11
• Combustion air preheating	B-13
• Refractory materials	B-15
• Furnace covers	B-17
• Overall furnace efficiency summary	B-20
Sample calculations (reverberatory furnaces)	
• Refractory materials	B-21
• Overall Furnace efficiency summary	B-25
Economic evaluation	B-26

HEAT TREATING

General considerations	B-27
Heat treat data input	B-28
Tables, graphs, and charts	B-29
Sample calculations (energy related)	B-33
• Upgrading furnace linings	B-33
• Improving combustion efficiency	B-36

B. Continued

Page

• Combustion air preheating	B-38
• Overall furnace efficiency	B-38
Economic evaluation	B-39

LADLE HEATING

General	B-40
Load operational data fact sheet	B-41
Graphs, tables, and charts	B-42
Sample calculations (energy related)	B-45
• Ladle covers	B-45
• Combustion systems	B-46
• Insulation	B-47
Economic Evaluation	B-49

C. COKE FUEL MELTING (CUPOLA)

General	C-1
Coke usage	C-1
Coke bed calculations	C-1
Standard calculation format	C-2
Operation of special cupolas	C-2
Graphs, tables, and charts	C-2
Coke to metal ratio	C-10
Special cupola melting conditions	C-11
Hot blast systems	C-11
Divided blast cupola	C-12
Oxygen enriched blast system	C-13
Overall energy savings	C-13
Coke versus electricity	C-15

D. GAS-FIRED SCRAP PREHEATING

General	D-1
Charge Preheat Data Fact Sheet	D-2
Oxygen-fuel assisted melting	D-4
Economic Evaluation	D-5

D. Continued	<u>Page</u>
E. <u>ENERGY SAVING CHECK LIST</u>	
Infiltration	E-1
HVAC	E-1
Make-up air	E-2
Insulation	E-2
Lighting	E-2
Boilers	E-2
Steam lines and traps	E-3
Fans, pumps, and motors	E-3
Domestic hot and cold water	E-3
Compressed air systems	E-4
Welding operations	E-6
Process and manufacturing operations	E-7
Material handling and transportation systems	E-9
Paint line operations	E-10

SECTION I

INTRODUCTION

The material presented in this energy management work book contains all the necessary documentation required for:

- Recording present energy usage
- Recording present energy cost
- Recording production statistics
- Calculation of present plant efficiency
- Construction of electric load profiles
- Equipment data recording

Equipped with the above recorded data and the mathematical models presented in Section II of this work book, a foundry energy manager can calculate potential energy savings associated with installation of energy-saving devices on:

- Gas-fired melt furnaces
- Electric melt furnaces
- Heat treat furnaces
- Gas ladle preheating
- Coke-fired cupolas

An economic analysis can be made to determine the cost effectiveness of the proposed equipment modifications. The methodology for computing the payback period is shown in Section II. If the simple payback method shows unfavorable results, a more in-depth economic analysis should be made utilizing the life-cycle cost principals. This method takes into account, cost of money, energy escalation costs, equipment depreciation, tax credits, etc. Life-cycle costing will give results pertaining to rate of return on investment.

PART A

ENERGY USE TABLES AND PRODUCTION STATISTICS

ELECTRICAL POWER USAGE

BILLING PERIOD	ENERGY KWH	BILLING DEMAND	POWER FACTOR	ENERGY CHARGE	FUEL ADJUSTMENT* CHARGE	DEMAND CHARGE	GROSS BILL	NET BILL
JANUARY								
FEBRUARY								
MARCH								
APRIL								
MAY								
JUNE								
JULY								
AUGUST								
SEPTEMBER								
OCTOBER								
NOVEMBER								
DECEMBER								
TOTALS								

AVERAGE POWER COST \$ _____ KWH = \$ _____ /KWH

REMARKS:

ANNUAL GAS CONSUMPTION

PERIOD	THERMS	BTU X 10 ⁶	COST
TOTALS			

HEAT CONTENT OF GAS = _____ BTU/CU FT (FROM BILL)

100,000 BTU = 1 THERM

COST OF GAS = \$ _____ = \$ _____ PER THERM
THERMS

REMARKS:

ANNUAL COKE CONSUMPTION

PERIOD	TONS	BTU X 10 ⁶	COST
TOTALS			

AVERAGE COST OF COKE = \$ _____ TONS = \$ _____ PER TON

1 LB. OF COKE = 12,500 BTU

REMARKS:

ANNUAL OIL CONSUMPTION

PERIOD	GALLONS	BTU X 10 ⁶	COST
TOTALS			

AVERAGE COST OF OIL = \$ _____ GALLONS = \$ _____ PER GALLON

REMARKS:

ANNUAL PROPANE CONSUMPTION

PERIOD	GALLONS	BTU X 10 ⁶	COST
TOTALS			

REMARKS:

ANNUAL PRODUCTION

YEAR _____

METAL CAST _____

PERIOD	MELT TONS	SHIPPED TONS	HEAT TREAT TONS	SALES VALUE
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				
TOTALS				

AVERAGE MELT TONS/DAY = _____

REPORTED % SCRAP _____

REPORTED % MELT LOSS _____

AVERAGE FOUNDRY YIELD % _____

TABLE 6

PLANT EQUIPMENT HORSEPOWER LIST

[illegible]

TABLE 7

DESCRIPTION AND FLOW RATES OF GAS-FIRED EQUIPMENT

EQUIPMENT	TYPE	BURNERS		OPERATION		AVERAGE CFH	MAXIMUM CFH
		NO.	TYPE	HRS/DAY	DAYS/MO		
TOTALS							

TABLE 8

PRESENT ENERGY-EFFICIENCY RECORD

MONTH OR YEAR RECORDED _____

UNITS OF PRODUCTION _____

FUEL COSTS

- Electricity \$ _____
- Natural Gas _____
- Propane _____
- Oil _____
- Coke _____
- Other _____

TOTAL _____

ENERGY USED

- KWH _____ x 3,412 Btu = _____ Btu x 10⁶
- Mcf Gas _____ x 1/ _____
- Gal. Propane _____ x 91,600 Btu = _____
- Gal. Oil _____ x 140,000 Btu = _____
- Coke - lb. _____ x 12,500 Btu = _____
- _____ = _____

TOTAL BTU _____

ENERGY USED PER UNIT OF PRODUCTION

$\frac{\text{(Million Btu)}}{\text{(Units)}} = \text{Btu x } 10^6/\text{Ton}$

COST PER MILLION BTU

$\frac{\text{(Energy Cost)}}{\text{(Million Btu)}} = \text{Cost/Btu x } 10^6$

COST PER UNIT OF PRODUCTION

$\frac{\text{(Total Cost)}}{\text{(Units)}} = \text{Cost/Unit}$

1/ 1 Mcf = 1,000 cu.ft./hr - See Gas Bill for Btu content/cu.ft.

POTENTIAL ENERGY-EFFICIENCY RECORD

MONTH OR YEAR RECORDED _____

UNITS OF PRODUCTION _____

FUEL COSTS

- Electricity \$ _____
- Natural Gas _____
- Propane _____
- Oil _____
- Coke _____
- Other _____

TOTAL _____

ENERGY USED

- KWH _____ x 3,412 Btu = _____ Btu x 10⁶
- Mcf Gas _____ x 1/ _____
- Gal. Propane _____ x 91,600 Btu = _____
- Gal. Oil _____ x 140,000 Btu = _____
- Coke - lb. _____ x 12,500 Btu = _____
- _____ = _____

TOTAL BTU _____

ENERGY USED PER UNIT OF PRODUCTION

$\frac{(\text{Million Btu})}{(\text{Units})}$ = _____ Btu x 10⁶/Ton

COST PER MILLION BTU

$\frac{(\text{Energy Cost})}{(\text{Million Btu})}$ = _____ Cost/Btu x 10⁶

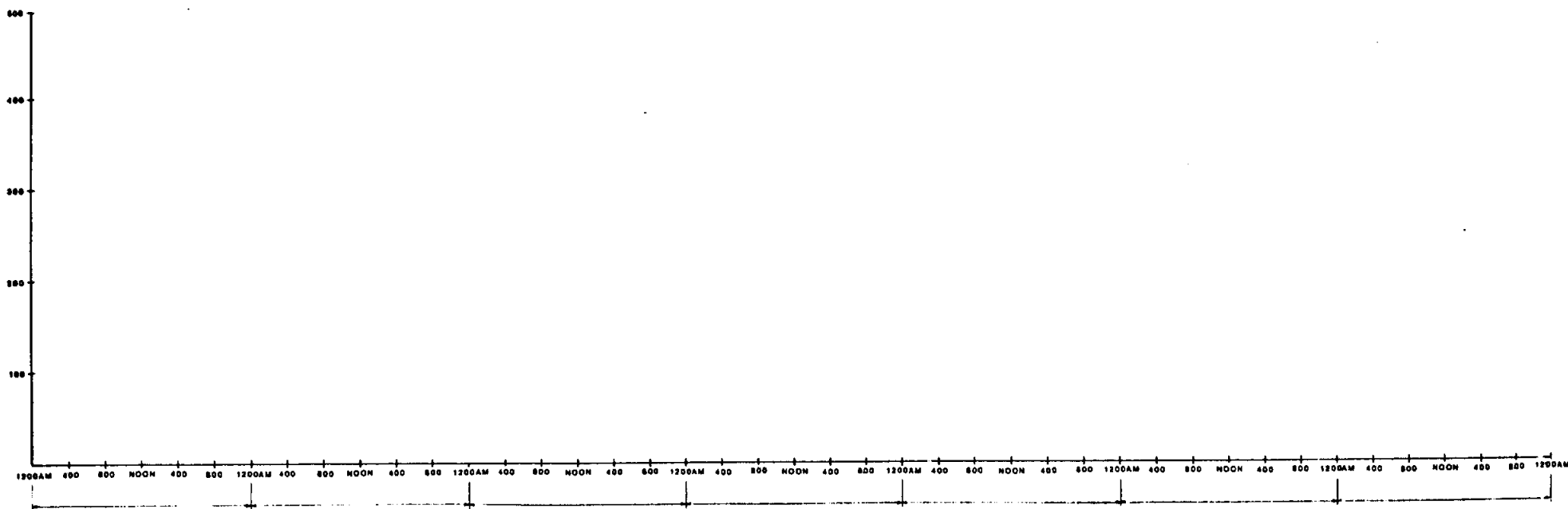
COST PER UNIT OF PRODUCTION

$\frac{(\text{Total Cost})}{(\text{Units})}$ = _____ Cost/Unit

1/ 1 Mcf = 1,000 cu.ft./hr - See Gas Bill for Btu content/cu.ft.

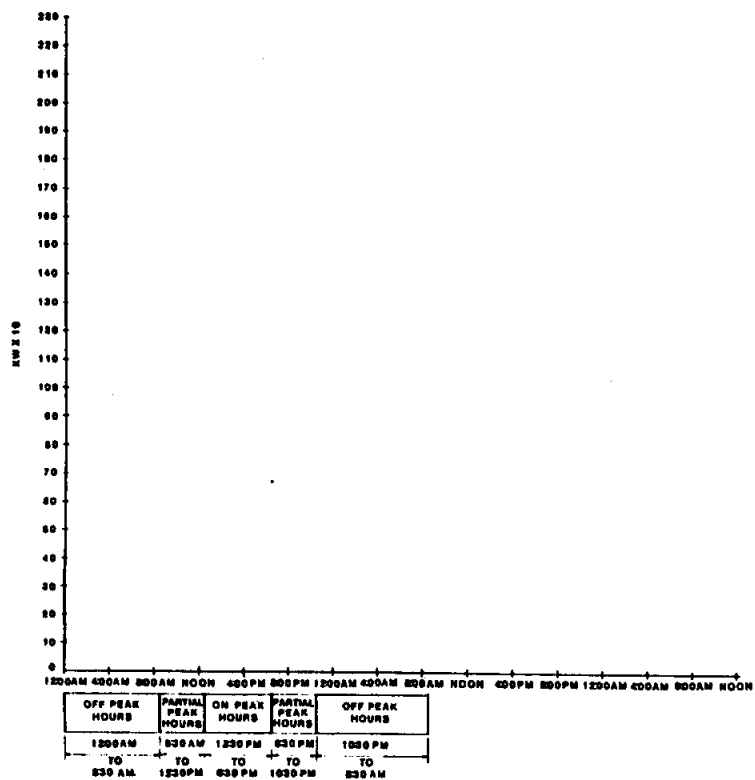
PART B

OPERATIONAL DATA FACT SHEETS



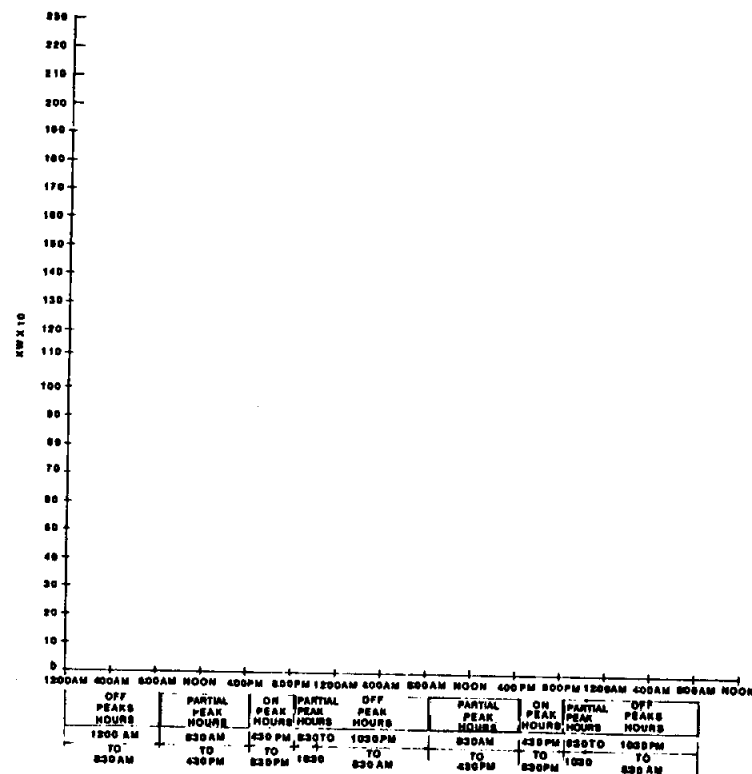
KILOWATT DEMAND LOAD PROFILE

FIGURE 1



KILOWATT DEMAND PROFILE (SUMMER)

FIGURE 2



KILOWATT DEMAND LOAD PROFILE (WINTER)

FIGURE 3

OPERATIONAL DATA FACT SHEET

ARC FURNACE DATA

Furnace make _____ Electrode Dia. _____ inches
 Model _____ Transformer _____ KVA
 Shell Dia. _____ FEET Primary _____ Volt
 Depth _____ INCHES Taps 1st _____ Volt
 Capacity _____ TONS 2nd _____ Volt
 3rd _____ Volt

Output _____ Tons/YR
 Alloy _____
 Melt cycle _____ minutes
 Heat size _____ tons
 Heats per day _____
 Taping temperature _____ °F
 No. of Back changes _____
 No. of slag cycles _____
 Blow down cycles O₂ _____ minutes
 C _____ minutes

Type of fume collection:

Furnace pressure _____ oz
 Exhaust _____ CFM
 Water Cooling _____ GPM
 Roof _____, Gland _____, Slag Door _____, Base _____,
 Water temperature in _____ °F, out _____ of
 Type of refractory lining.

REMARKS:

OPERATIONAL DATA FACT SHEET
CORELESS INDUCTION FURNACE

Furnace make _____ Transformer KVA _____
Model _____ Primary Voltage _____
Capacity _____ Secondary Voltage _____

Output _____ tons/yr.
_____ tons/day

Alloy _____

Melt cycle _____ minutes

Tap Quantity _____ lbs.

Charge Quantity _____ lbs.

Tap temperature _____ °F

Holding temperature _____ °F

Slag cycle _____ minutes

Fume collection _____ CFM

Water cooling....GPM, Temp.....in °F.....Out °F

Type of Refractory _____

Energy consumption _____ KWH/YR

Energy Cost _____ ¢/KW

REMARKS:

OPERATIONAL DATA FACT SHEET

GAS MELT FURNACE DATA

Metal type: _____ Annual tons _____
 Pouring or tap temperature _____ °F
 Heat content Btu/lb _____ Shifts/day _____
 Melting period hrs. _____ Holding period hrs. _____

METHOD OF MELTING

CRUCIBLE

REVERB

Metal melted/hr.lbs.	_____	_____
Burner rating Btu/hr	_____	_____
Total gas usage/hr	_____	_____
Capacity of furnace lbs.	_____	_____
Crucible diameter	_____	_____
Area of metal radiation sq.ft.	_____	_____
Area of refractory wall:		
Below metal	_____	_____
Above metal	_____	_____
Thickness of wall	_____	_____
Door open area or dip well sq.ft.	_____	_____
Mean temperature of walls °F	_____	_____
Outer temperature of walls T ₁	_____	_____
Inner temperature of walls T ₂	_____	_____
Present refractory K value	_____	_____
Proposed refractory K value	_____	_____
Rs value for refractory	_____	_____
CO ₂ flue gas reading	_____	_____
Combustion air cfm	_____	_____
Combustion air wg	_____	_____
Flue gas (or comb.) temperature	_____	_____
Ambient temperature °F	_____	_____
Time of day used	_____	_____
Days/year used	_____	_____
Energy cost/therm \$	_____	_____

OPERATIONAL DATA FACT SHEET

HEAT TREATING UNIT NO. _____	
FURNACE MAKE _____	BURNER MAKE _____
MODEL _____	MODEL _____
SIZE _____ WFT.	TYPE _____ SIZE _____ BTU/HR
CAPACITY _____ LBS.	FUEL _____
TYPE OF LINING _____	RECUPERATOR MAKE _____
WALL THICKNESS _____ INCH	MODEL _____ TEMP _____ °F
BLOWER MAKE _____	TYPE _____ SIZE _____
MODEL _____	CONTROLS MAKE _____
SIZE _____ CFM. PRESS _____ "WG	TYPE _____
VOLT _____ HP _____	
TYPE OF HEAT TREAT CYCLE _____ ALLOY _____	
HEAT TREAT CYCLE - HEATUP _____ HRS	FUEL/AIR RATIO _____ HIGH _____ LOW _____
- SOAK _____ HRS	FLUE TEMPERATURE _____ °F _____ °F
-COOL DOWN _____ HRS	SHELL MEAN TEMPERATURE _____ °F
CYCLES PER WEEK _____	FURNACE PRESSURE _____ "WC
TEMPERATURE _____ °F	
AVERAGE LOAD _____ LBS	FLUE ANALYSIS (HIGH) _____ % CO
CASTING _____ LBS	_____ % O ₂
BASKETS _____ LBS	_____ % CO ₂
STOOLS _____ LBS	LOW _____ % CO
LOAD DENSITY _____ LBS/WFT	_____ % O ₂
QUENCH _____ AIR, _____ H ₂ O _____ OIL	_____ % CO ₂
QUENCH TEMPERATURE _____ °F	
	FUEL CONSUMPTION _____ THERMS/CYCLE

WALL AREA _____ SQ.FT.

WALL TEMPERATURE HOT FACE T₁ _____ °F

WALL TEMPERATURE COLD FACE T₂ _____ °F

AMBIENT TEMPERATURE _____ °F

EXTERNAL SURFACE AREA _____ SQ.FT.

ENERGY COST/THERM \$ _____

HEAT TREAT LOADS/DAY _____

HEAT TREAT LOADS/YEAR _____

TABLE 4

BURN-OUT FURNACES

FURNACE MAKE _____		BURNER MAKE _____	
MODEL _____		NO. OF BURNERS _____	
SIZE _____		TYPE _____ SIZE _____ BTU/HR	
CAPACITY _____ LBS.		FUEL _____	
TYPE OF LINING _____		AFTER BURNER MAKE _____	
EXHAUST BLOWER MAKE _____		MODEL _____	
MODEL _____		TYPE _____ SIZE _____	
SIZE _____ CFM. PRESS _____ "WG		OPERATING HOURS	
VOLT _____ HP _____		MAIN BURNER _____	
		AFTER BURNER _____	
TYPE OF FURNACE CYCLE _____ N/A			
FURNACE CYCLE - HEATUP _____ HRS		FUEL/AIR RATIO _____	
- SOAK _____ HRS		HIGH _____ °F LOW _____ °F	
CYCLES PER WEEK _____		FLUE TEMPERATURE _____ °F	
TEMPERATURE _____		FURNACE PRESSURE _____	
LOAD DENSITY - _____		CO ₂ IN FLUE GAS _____	
		FUEL CONSUMPTION _____ Therms/Day	
REMARKS:			

OPERATIONAL DATA FACT SHEET

LADLE PREHEAT DATA

LADLE CAP TONS _____ HEAT CYCLES/DAY _____
LADLE AREA INSIDE _____ SQ FT. LINING THICKNESS _____
COVERED _____ TYPE OF LINING _____
INSIDE TEMP _____ °F OUTER SHELL TEMP _____ °F
AMBIENT TEMP _____ °F
GAS USAGE/HR _____ CU FT. CO₂ READING _____
COMBUSTION AIR _____ CFM PRESSURE _____ WG
PREHEAT CYCLE TIME _____ HRS FLUE TEMP _____ °F
REFRACTORY K VALUE _____ RS VALUE _____
BLOWER HP _____ RECUPERATOR EFFCY _____
FUEL COST/THERM \$ _____ ANNUAL USE _____ BTU x 10⁶
NUMBER OF UNITS IN USE _____

REMARKS:

CUPOLA DATA

REMARKS:

OPERATIONAL DATA FACT SHEET

HEAT TREAT FURNACES (ELECTRIC)

FURNACE MAKE	_____	MODEL	_____
SIZE	_____	INSIDE	_____
		OUTSIDE	_____
CAPACITY	_____	LBS.	_____
		TYPE	_____
WALL THICKNESS	_____	TEMP. RANGE	_____ °F
HEATING ELEMENT	_____	VOLTS	_____
		AMPS	_____
		kW	_____
HEAT TREAT CYCLE	-	HEAT-UP	_____ HRS
		SOAK	_____ HRS
		COOL DOWN	_____ HRS
CYCLES PER WEEK	_____		
ELECTRICAL CONSUMPTION	_____ KWH/CYCLE		
REMARKS:			

OPERATIONAL DATA FACT SHEET

GAS-FIRED SCRAP PREHEAT

METAL TYPE _____ DENSITY _____ LBS/CU.FT.

PREHEAT TEMPERATURE _____ °F. CYCLE _____ HRS

MELTING CAPACITY _____ TONS/DAY. MELT RATE _____ TONS/HR

FUEL AVAILABLE FOR PREHEAT _____ COST/THERM

CHARGE SIZE/WEIGHT PER BATCH _____ LBS

PREHEAT BURNER RATING BTU/HR _____

CO₂ FLUE GAS READING _____ TEMPERATURE _____ °F

COMBUSTION AIR CFM _____ PRESSURE _____ WG

AMBIENT TEMPERATURE _____ TIME OF DAY USED _____

SHIFTS PER DAY _____ DAYS/YEAR _____

REMARKS:

SECTION II

INTRODUCTION

This section provides all necessary charts, graphs, tables, and mathematical formula for the development of energy savings in quantative form for:

- Electric power and cost savings relative to the melting of metal in all available types of furnaces. By utilizing hypothetical mathematical models it will be shown how to cut energy cost and/or consumption by improving power factors, installing demand limit controls, changing to "off-peak" melting and demand shifting.
- Gas energy reduction relative to melting, heat treating, and ladle preheating. By utilizing hypothetical mathematical models it will be shown how to reduce energy cost and/or consumption by improving combustion efficiencies, installation of ceramic fiber lining, installation of covers, and adding combustion air preheating.
- Reduction of coke usage in cupola melting by upgrading equipment such as adding hot blast via stack gas recuperation divided blast and oxygen enrichment. Also shown is the comparative energy usage for cupola versus electric melting.

PART A

ELECTRIC MELTING

GENERAL

As stated previously in Section 1 of this report, approximately 34% of the total energy input (all fuels) to a typical steel foundry is in the form of electricity, of this 34% approximately 60% is attributed to the melting of metal. This section deals with energy and cost savings in electric melting operations and covers the following areas.

- Furnace operation
- Energy usage
- Demand
- Demand control
- Off-peak melting
- Demand shifting
- Power factor correction

INPUT DATA

The required input data needed to analyze present melting operations, from the standpoint of energy consumption is:

- Electric utility bills for the past twelve months
- Kilowatt demand load profile
- Rate schedule for summer and winter "Time of Day" billing

The electric energy usage for 1979 calendar year is shown in Table 1. The kilowatt demand load profile covers a period of 48 hours and represents an electrical demand requirement for electric melting (See Figure 1). The load profile was developed from the kilowatt demand printout (See Table 2). From Table 2, it should be noted that the kilowatt demand for each five-minute interval for each 24-hour period is listed.

TABLE 1. ELECTRICAL POWER USAGE

BILLING PERIOD	ENERGY KWH	BILLING DEMAND	POWER FACTOR	ENERGY CHARGE	FUEL ADJUSTMENT CHARGE	DEMAND CHARGE	GROSS BILL	NET BILL
JANUARY 1979	376,800	2,291	.97	11,570	(638)	5,394	17,602	\$ 16,964.00
FEBRUARY 1979	386,400	2,255	.98	10,757	(647)	5,318	16,722	16,075.00
MARCH 1979	367,200	2,279	.99	10,136	(648)	5,361	16,145	15,497.00
APRIL 1979	415,200	N/A	N/A	N/A	N/A	N/A	N/A	16,728.00
MAY 1979	376,800	2,266	.98	10,443	(548)	5,341	16,332	15,784.00
JUNE 1979	376,800	N/A	N/A	N/A	N/A	N/A	N/A	15,900.00
JULY 1979	228,000	2,281	.98	6,646	(450)	5,373	12,469	12,019.00
AUGUST 1979	384,000	2,262	.99	10,748	(476)	5,333	16,557	16,081.00
SEPTEMBER 1979	434,400	2,404	.99	12,117	(509)	5,634	18,260	17,751.00
OCTOBER 1979	432,000	2,443	.98	12,650	(505)	5,717	18,872	18,367.00
NOVEMBER 1979	468,000	2,500	.98	14,149	(521)	5,838	20,508	19,987.00
DECEMBER 1979	427,200	N/A	.99	N/A	(256)	N/A	15,029	14,772.00
TOTALS	4,672,800							\$195,925.00

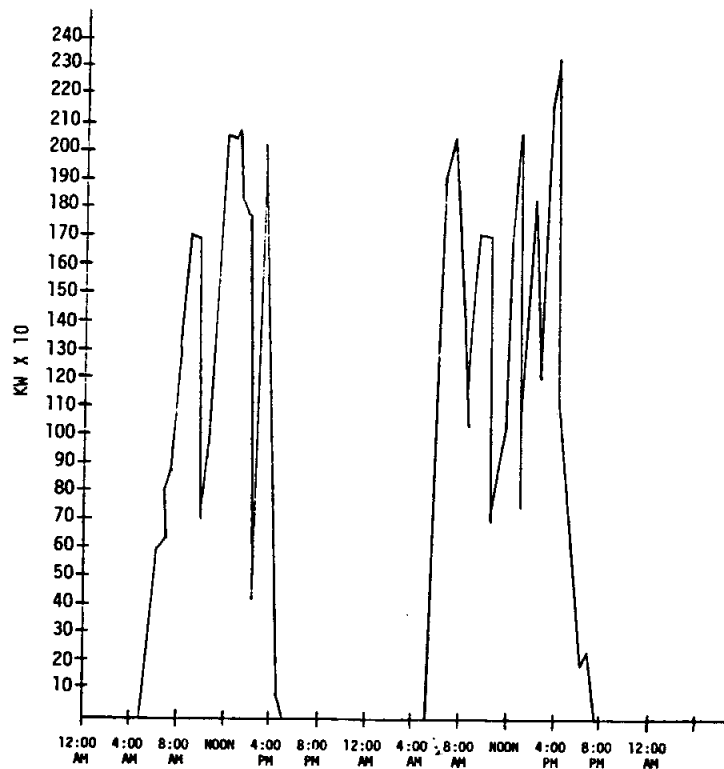


FIGURE 1. ELECTRICAL LOAD TABLES

Start
Time
12:05am
Column

[illegible]Kilowatt
Demand
Column

Finish
Time
12:00pm
Column

Foundries with a separate electrical service to their melting furnaces can develop their own in-house kilowatt load profile in the following manner. Prepare a chart, using graph paper with one-tenth of an inch/to one inch divisions, recording time along abscissa axis and kilowatt demand along ordinate axis. Along the abscissa axis set out the "time of day" billing hours. Setting up the graph in this manner will indicate if the high kilowatt demands are occurring during the "on peak" hours (See Figure 2). From the kilowatt demand printout, record the thirty minute kilowatt demands for chosen time periods. When all 30-minute kilowatt demands have been recorded, connect all points to obtain profile of load. The procedure for developing a winter kilowatt load profile is the same as "summer", but the "time of day" billing hours change (See Figure 3).

Foundries that are not provided with a kilowatt demand printout for their electric melting operation or have only one electrical service for both melting and general plant service will need to install submetering of the service feeders.

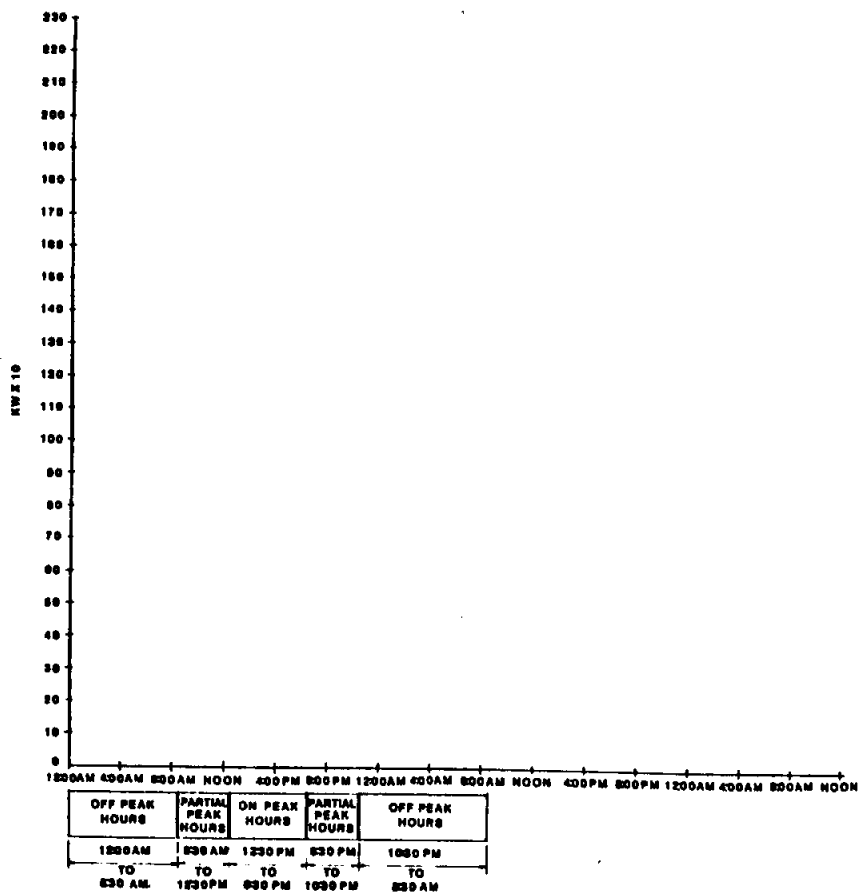
Using a three-phase tap-type recording ammeter and a clip on type power factor meter the necessary data can be obtained to find the kilowatt demand.

Example

If the ammeter recorded 400 amperes with a 0.80 power factor the kilowatts would be as follows:

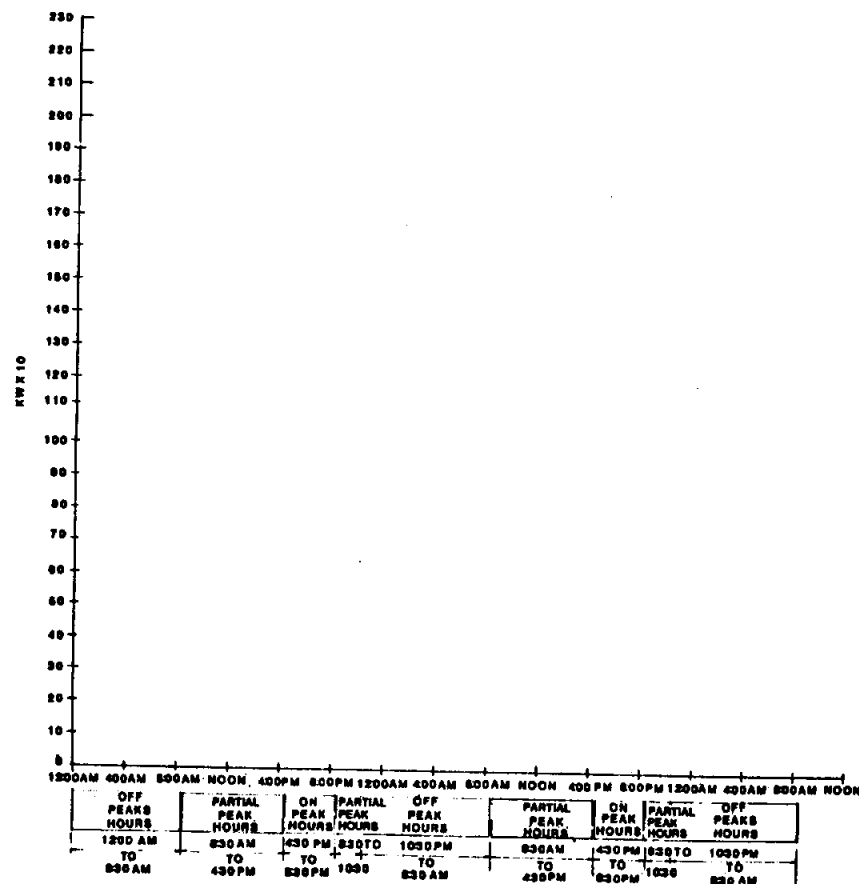
$$\frac{I \times E \times 1.73 \times PF}{1000}$$
$$\frac{400 \times 480 \times 1.73 \times .80}{1000} = 265 \text{ kilowatts}$$

From the above reading the kilowatt load profile can be developed.



KILOWATT DEMAND PROFILE (SUMMER)

Figure 2



KILOWATT DEMAND LOAD PROFILE (WINTER)

Figure 3

OFF-PEAK METAL MELTING

Utilizing "off-peak" hours for metal melting, substantial cost savings can be realized by lowering the demand and energy charges.

Figure 4 illustrates a total demand load of 2,300 kilowatts, of this amount approximately 59% or 1,357 kW is attributed to melting of metal, the remainder is base plant electrical load.

The following sample calculations illustrate the electrical cost for demand, energy and fuel adjustment charges for melting in on-peak and off-peak hours.

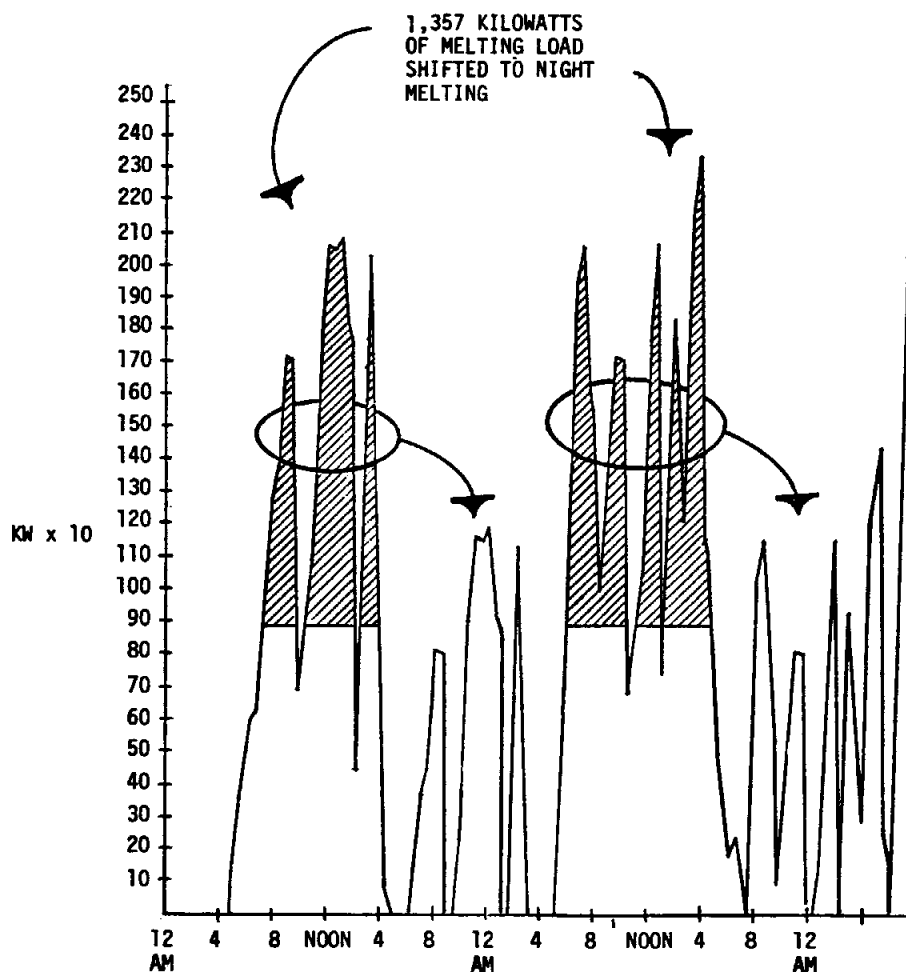


FIGURE 4.

SAMPLE CALCULATION (On-Peak Period)

Demand Charges:

On-peak per kilowatt of maximum demand

Total on-peak 1369 kW at \$2.50 \$ 3,422

Plus "partial peak" per kilowatt of maximum demand

Total partial peak 1363 kW at \$0.30 \$ 408

Plus off-peak, per kilowatt of maximum demand

Total off-peak 1358 kW no charge \$ 0

Subtotal

\$ 3,830

Energy Charges:

On-peak, per kilowatt hour: 12:30pm to

6:30pm 4-5hrs/day

Total kilowatt hours 98,571 x ¢0.022/kwh \$ 2,168

Partial peak, per kilowatt hour: 8:30am to

12:30pm and 6:30pm to 10:30pm 8hrs/day

Total kilowatt hours 145,135 x ¢0.019/kwh \$ 2,757

Off-peak, per kilowatt hour: 10:30pm to

8:30am 10hrs/day

Total kilowatt hours 183,875 x ¢0.010/kwh \$ 1,839

Subtotal

\$ 6,764

Fuel Adjustment Charges:

Total kilowatt hours = 427,582 x 0.04063 \$ 17,372

Grand total for (demand, energy and fuel
adjustment charges)

\$ 27,966

Above calculations are based on normal day shift working hours and summer "time of day" billing rates for a 30-day period. Figures are abstracted from power company metered print-outs.

Off-Peak Melting

Demand Charges:

"On-peak" per kilowatt of maximum demand

Total on-peak none at \$2.50 \$ 0

Plus "partial peak" per kilowatt of maximum demand

Total partial peak none at \$0.30 \$ 0

Plus "off-peak" per kilowatt of maximum demand

Total off-peak 1239 at no charge \$ 0

Subtotal \$ 0

Energy Charge:

"On-peak", per kilowatt hour: 12:30pm to 6:30pm 6hrs/day

Total kilowatt hours none x ¢0.022/kwh \$ 0

"Partial peak" kilowatt hours: 8:30am to 12:30pm
and 6:30pm to 10:30pm 8hrs/day

Total kilowatt hours none x ¢0.019/kwh \$ 0

"Off-peak" kilowatt hours: 10:30pm to 8:30am 10hrs/day

Total kilowatt hours 427,582 x ¢0.010/kwh \$ 4,275

Subtotal \$ 4,275

Fuel Adjustment Charges:

Total kilowatt hours = 427,581 x ¢0.04063 \$17,372

Grand total for (demand, energy and fuel adjustment
charges) \$21,647

Potential cost savings by shifting to off-peak melting would be
\$27,966 - \$21,647 = \$6,319 or 22.5% savings for the 30-day period.

DEMAND SHIFTING AND DEMAND CONTROL

If night melting is not possible, demand shifting and control will permit metal melting during normal "on-peak" day time hours and still save substantial costs. Demand shifting will extend the melting period; this permits the sequential operation of the furnaces, thereby reducing the peak maximum demand.

With uncontrolled operation, large kilowatt demands are developed which produces low demand factors and low efficiency of power usage. Figure 5 is representative of an uncontrolled operation of power input to several furnaces. Figure 6, indicates how the kilowatt demand can be reduced by extending the hours of melting operations, the demand limit is set at 1,700 kilowatts. The sample calculations illustrate the potential cost savings if demand shifting and control is utilized. To insure complete control of a set maximum demand, an automatic demand controller should be installed, this controller automatically regulates or limits operation in order to prevent a set maximum demand from being exceeded. With the monitored information, the controller can calculate when an overload of the set demand will occur. The controller will delay any shed action to allow time for loads to shed normally. When it is determined that it will be necessary to shed one or more loads to keep from exceeding the set kilowatt demand, the controller will shed the necessary load. This means that shedding will occur only once during a demand interval and maximum use of available power will be realized.

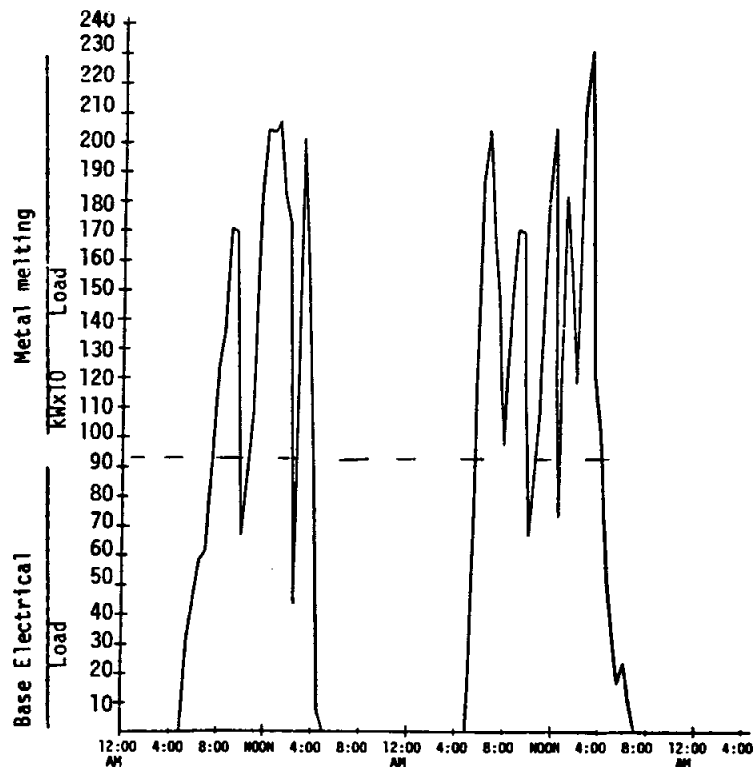


FIGURE 5. ELECTRICAL LOAD PROFILE (UNCONTROLLED)

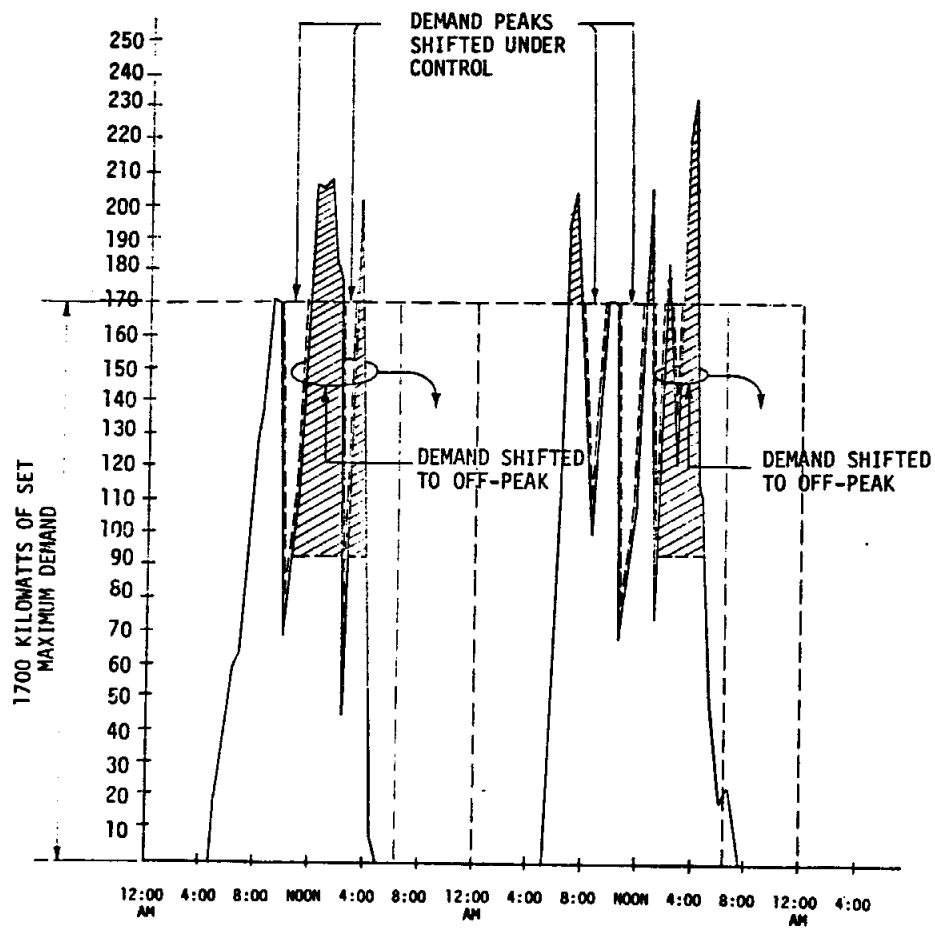


FIGURE 6. ELECTRICAL LOAD PROFILE (CONTROLLED)

Sample Calculations (Uncontrolled Operation)

Demand Charges:

"On peak" per kilowatt of maximum demand

Total on peak 1,033 kw at \$2.50 \$ 2,507

Plus partial peak per kilowatt of maximum demand

Total partial peak 998 kw at \$0.30 \$ 299

Plus "off-peak" per kilowatt of maximum demand

Total off-peak 994 kw no charge \$ 0

Subtotal \$ 2,806

Energy Charge:

"On peak", per kilowatt hour: 12:30pm to

6:30pm 6 hrs/day

Total kilowatt hours 98,571 x ¢0.022/kwh \$ 2,168

"Partial peak" kilowatt hour: 8:30am to

12:30pm and 6:30pm to 10:30pm 8hrs/day

Total kilowatt hours 145,135 x ¢0.019/kwh \$ 2,757

"Off-peak" per kilowatt hour: 10:30pm to

8:30am 10hrs/day

Total kilowatt hours 183,875 x ¢0.010/kwh \$ 1,839

Subtotal \$ 6,764

Fuel Adjustment Charges:

Total kilowatt hours = 427,582 x 0.04063 \$ 17,372

Grand total for (demand, energy and fuel

adjustment charges) \$ 26,942

Sample Calculations (Controlled Operation)

Demand Charges:

"On peak" per kilowatt of maximum demand

Total on peak none kw at \$2.50 \$ 0

Plus partial peak per kilowatt of maximum demand

Total partial peak 998 kw at \$0.30 \$ 299

Plus "off-peak" per kilowatt of maximum demand

Total off-peak 994 kw no charge \$ 0

Subtotal \$ 299

Energy Charge:

"On peak", per kilowatt hour: 12:30pm to

6:30pm 6 hrs/day

Total kilowatt hours none x ¢0.022/kwh \$ 0

"Partial peak" kilowatt hour: 8:30am to

12:30pm and 6:30pm to 10:30pm 8hrs/day

Total kilowatt hours 145,135 x ¢0.019/kwh \$ 2,757

"Off-peak" per kilowatt hour: 10:30pm to

8:30am 10hrs/day

Total kilowatt hours 282,446 x ¢0.010/kwh \$ 2,824

Subtotal \$ 5,581

Fuel Adjustment Charges:

Total kilowatt hours = 427,582 x 0.04063 \$ 17,372

Grand total for (demand, energy and fuel

adjustment charges) \$ 23,252

DEMAND CONTROL

With a power demand controller installed on the power system supply to the furnaces, maximum kilowatt demand can be controlled.

The controller automatically regulates or limits operation in order to prevent a set maximum demand from being exceeded. The controller predetermines the demand limit and the demand interval. The sequence of operation is similar to that described under "load shifting and control".

Figure 7, illustrates the new load profile with demand set at 1,700 kW. Cost savings are the same as those computed under "Load Shifting and Control."

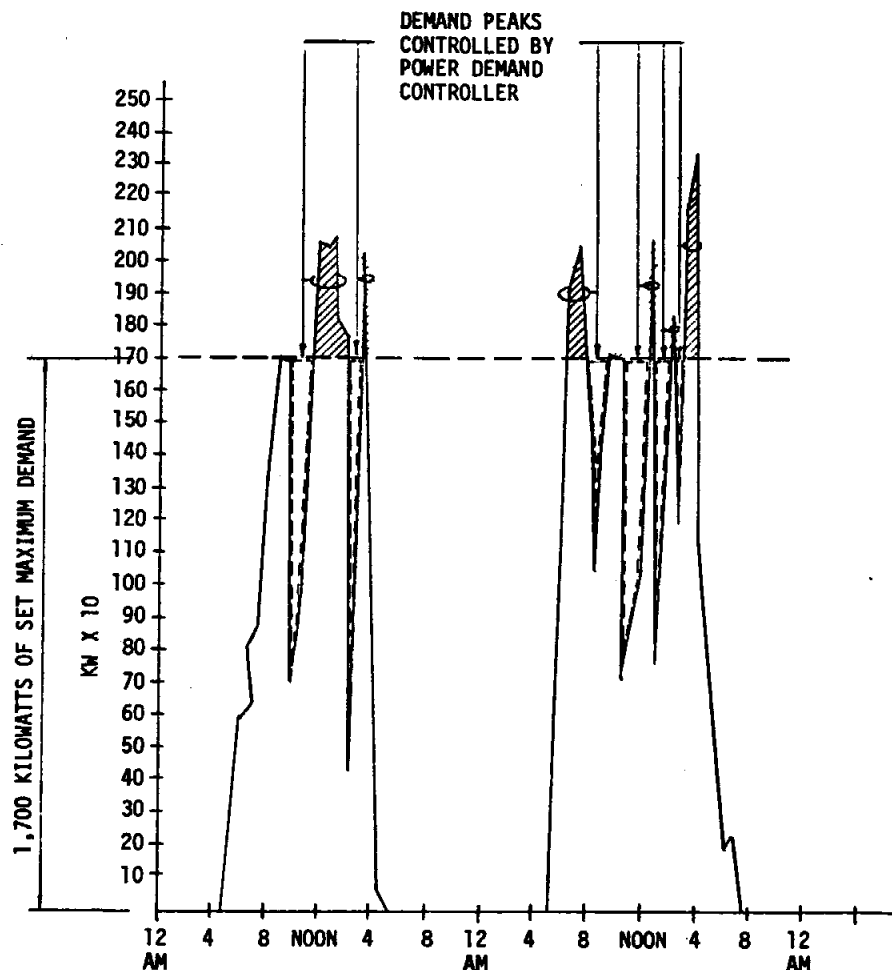


FIGURE 7. ELECTRIC LOAD PROFILE (DEMAND CONTROL)

POWER FACTOR CORRECTION

The electrical efficiency of the coreless induction furnace is approximately 76-81 percent with a power factor of approximately 90-98 percent, the channel furnace is approximately 94-95 percent with a power factor of 94-98 percent. With these high power factors designed into the furnaces, no additional correction is necessary.

On the other hand arc furnaces have an approximate power factor of 70%, if capacitors are not installed on furnace transformers. It should be noted that power factor improvement will not save in-plant energy or reduce the customer's power bill, but will save energy at the utility company power plant thereby reducing the nation's dependence on oil.

IMPROVED FURNACE DESIGN

Induction Furnaces

Improved profile of the power coil reduces the magnetic flux lines penetrating through the outside corners, which in turn minimizes eddy current loss, thereby improving furnace efficiency.

Use of castable backup refractory will eliminate the need for cooling coils and save the energy that would otherwise enter into the cooling water. The efficiency of the furnace can be increased as much as 10% with these improvements. A foundry producing 25 tons a day can save approximately \$17,000 per year. Using representative figures for this example the savings compute as follows:

Total energy required to melt 25 tons of metal per day =

$$\frac{25 \times 500 \text{ kwh/ton}}{0.76\% \text{ efficiency}} = 16,500 \text{ kwh}$$

10% improvement = $16,500 \times 0.10 = 1,650 \text{ kwh savings/day}$

Savings/year at 240 days = $1,650 \times 240 = 400,000 \text{ kwh}$

Average power at \$0.0427/kwh

$$400,000 \times \$0.0427 = \underline{\underline{\$17,000 \text{ savings/year}}}$$

Arc Furnaces

The installation of water-cooling on the sidewalls of the furnace will reduce downtime necessary for refractory replacement. With installation of water-cooled blocks there is about 10% increase in total furnace productivity; other benefits are:

- 80% decrease in side wall brick consumption
- Reduction of power "on-time" by 13%
- 3% energy savings
- 8% reduction in electrode consumption

The installation of solid-state furnace controls will automatically position the electrodes within the furnace. The control maintains more accurately the arc setpoint which give constant power input and longer refractory life. The resistance sensing compensates for reactance to allow more sensitive action to the arc resistance. With a constant arc stability it provides for a higher through-put, with a higher input power usage. The energy savings that can be realized are approximately 10 percent.

Electric Glo-Bar Reverberatory Melting Furnace (ERMF)

Installation of furnace covers over the charging and dipout wells and the bath will save energy.

Sample Calculation

Potential energy savings in covering a four-square-foot opening based on radiation losses of 20,000 Btu's/SF/hr for covered furnaces.

Four SF Area

Losses without cover = (4 x 20,000)	= 80,000 Btu/hr
Losses with cover = (4 x 500)	= 2,000 Btu/hr
Net reduction	= 78,000 Btu/hr
Losses per 10-hr day = (78,000 x 10)	= 780,000 Btu
kwh saved (780,000 ÷ 3412)	= 228 kwh
Annual savings (240 days x 228 x \$0.042)	= <u>\$2,298.00</u>

Graphite Rod Holding Furnace

As the graphite rod holding furnace is not a primary melting furnace, this furnace will not be addressed with regards to lost energy. The efficiency and utilization of energy input for metal holding is high. The power factor is maintained at near unity with this type of unit.

SUMMARY

POTENTIAL ANNUAL COST SAVINGS FOR ELECTRICAL ENERGY AND DEMAND ^{1/}					
ITEM	PRESENT CONDITIONS		POTENTIAL CONDITIONS		POTENTIAL ANNUAL COST SAVINGS \$
	ENERGY CONSUMED KWH	ENERGY AND DEMAND COST \$	ENERGY CONSUMED KWH	ENERGY AND DEMAND COST \$	
Off-Peak Melting	5,130,984	335,592	5,130,984	259,764	75,828
Demand Shifting and Demand Control	5,130,984	323,304	5,130,984	279,024	44,280
Demand Control Only	5,130,984	335,592	5,130,984	323,304	12,288
Furnace Covers	56,272	2,363	1,406	65	2,298
Improved Furnace Design	3,960,000	169,092	3,564,000	152,182	17,000

^{1/} Developed from sample calculations shown previously in this text.

1. Potential annual cost savings are based on 240 operating days per year.
2. Energy consumed per year is based on furnace loads only. Does not include plant base loads.
3. Average energy cost of \$0.06 per kwh based on 1980 rate schedules should be used in place of \$0.04 used in examples.
4. Potential energy savings shown are not all accumulative.

PART B

NATURAL GAS MELTING

GENERAL DESCRIPTION

This section deals with energy savings in gas melting operations:

Formulas, calculations, and graphs have been simplified within the Scope of the Project from the normally complex task of calculating heat transfers to reflect constant conditions during the process.

To investigate any process in depth, it is essential to establish parameters, calculate the data and plot results on a continuous basis to establish the limits of the operation and equipment, and identify any trends.

The work sheet lists the expected parameters for furnaces, burner and ancillary equipment and operational data to complete a "one shot" energy audit. This constitutes a base for any future improvements. A tape measure, thermometer, flue gas analyzer and flowmeters will be the tools needed.

GAS FURNACE DATA INPUT

Metal type:	<u>Aluminum</u>	Annual tons	<u>1,500</u>
Pouring or tap temperature	<u>1380</u>	⁰ F	
<u>1/</u> Heat content Btu/lb	<u>497</u>	Shifts/day	<u>One</u>
Melting period hrs.	<u>8</u>	Holding period hrs.	<u>16</u>
<u>Method of Melting</u>	<u>Crucible</u>	<u>Reverb</u>	
Metal melted/hr. lbs.	<u>2,000</u>	<u>2,000</u>	
Burner rating Btu/hr	<u>3.6×10^6</u>	<u>4.85×10^6</u>	
Total gas usage/hr CFH	<u>3,600</u>	<u>4,850</u>	
Capacity of furnace lbs.	<u>2,000</u>	<u>5,000</u>	
Crucible diameter	<u>36"</u>	<u>-</u>	
Area of metal radiation sq. ft.	<u>4.0</u>	<u>4.0</u>	
Area of refractory wall:			
Below metal sq. ft.	<u>110</u>	<u>40</u>	
Above metal sq. ft.	<u>-</u>	<u>40</u>	
Thickness of wall ins.	<u>6</u>	<u>6</u>	
Door open area or dip well sq. ft.	<u>-</u>	<u>-</u>	
Mean temperature of walls ⁰ F	<u>-</u>	<u>-</u>	
Outer temperature of wall T ₁	<u>100⁰F</u>	<u>100⁰F</u>	
Inner temperature of walls T ₂	<u>3,000⁰F</u>	<u>2,000⁰F</u>	
Present refractory K value	<u>N/A</u>	<u>6</u>	
Proposed refractory K value	<u>-</u>	<u>-</u>	
Rs value for refractory	<u>-</u>	<u>-</u>	
CO ₂ flue gas reading	<u>5% CO₂</u>		
Combustion air cfm	<u>N/A</u>	<u>N/A</u>	
Combustion air wg	<u>N/A</u>	<u>N/A</u>	
Flue gas temperature	<u>1,150⁰F</u>	<u>1,600⁰F</u>	
Ambient temperature ⁰ F	<u>-</u>	<u>-</u>	
Time of day used	<u>-</u>	<u>-</u>	
Days/year used	<u>240</u>	<u>240</u>	
Energy cost/therm \$	<u>\$0.30</u>		

1/ See Figure 1 for input data.

GRAPHS, TABLES AND CHARTS

The following graphs, tables and charts illustrated here are to be utilized for performing sample calculations for anticipated energy reduction measures.

Heat Content of Metals

The following graph (Figure No. 1) shows the heat content of numerous metals and alloys for various temperature ranges:

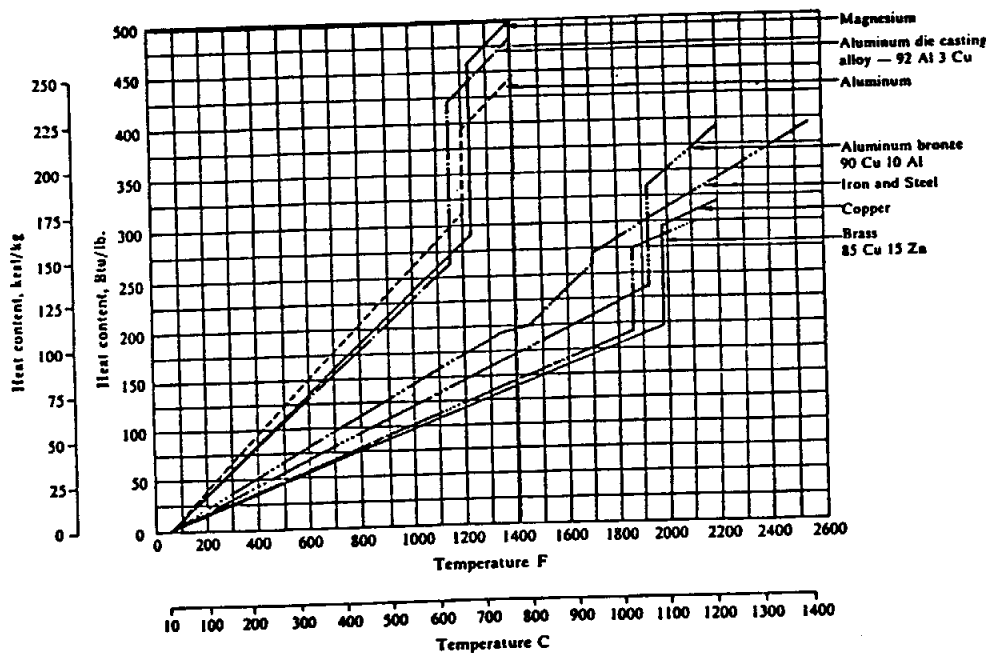


FIGURE 1. NORTH AMERICAN HANDBOOK

Example of use: With a 1400°F metal temperature, the heat content of aluminum die casting alloy is approximately 500 BTU/lb.

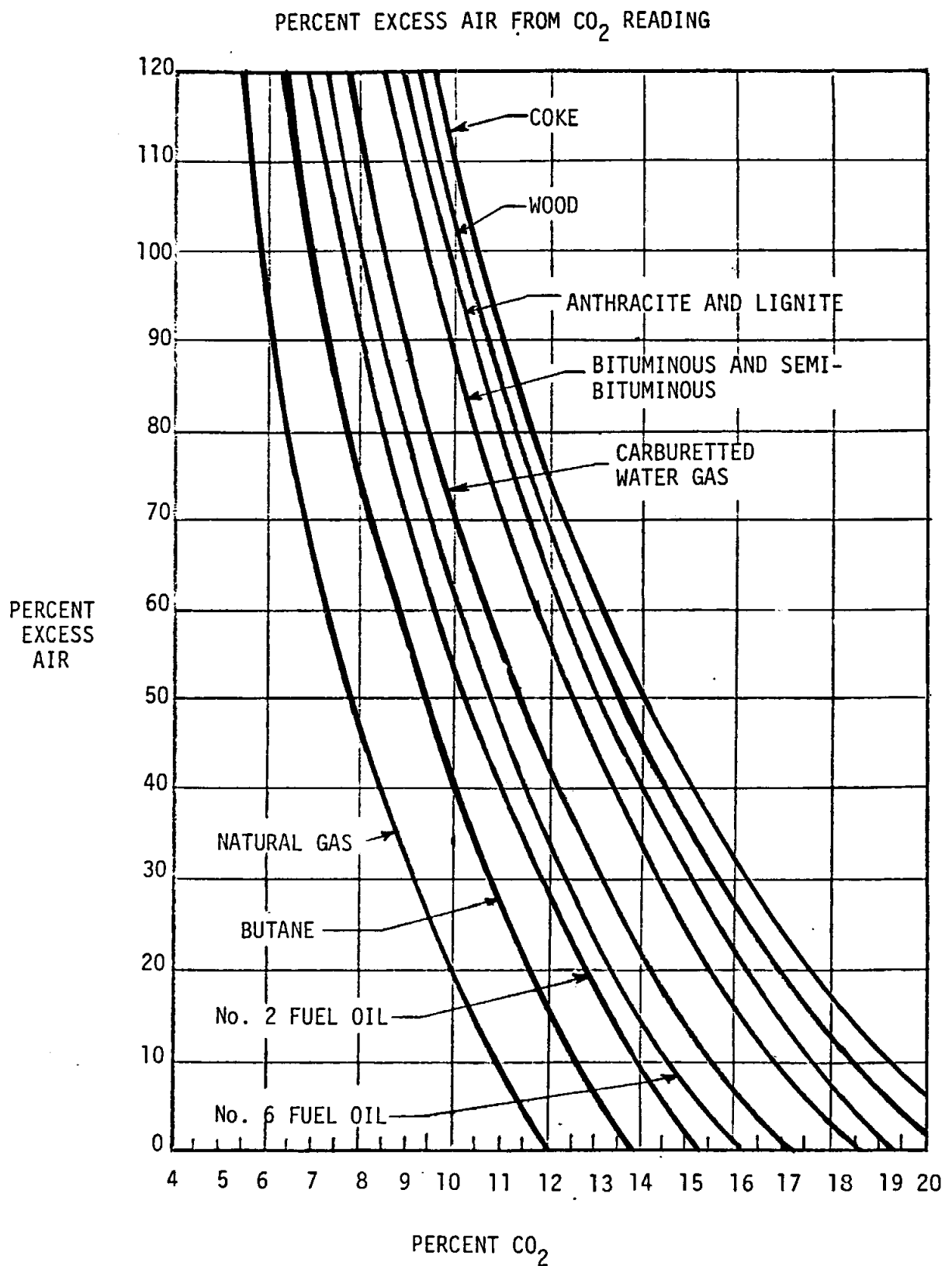


Figure No. 2

Source: North American Combustion Handbook.

Example of Use: A combustion analysis shows 6% CO₂ content of the flue gas, with natural gas burning equipment the excess air is approximately 90%.

PERCENT AVAILABLE HEAT

From North American Combustion Handbook

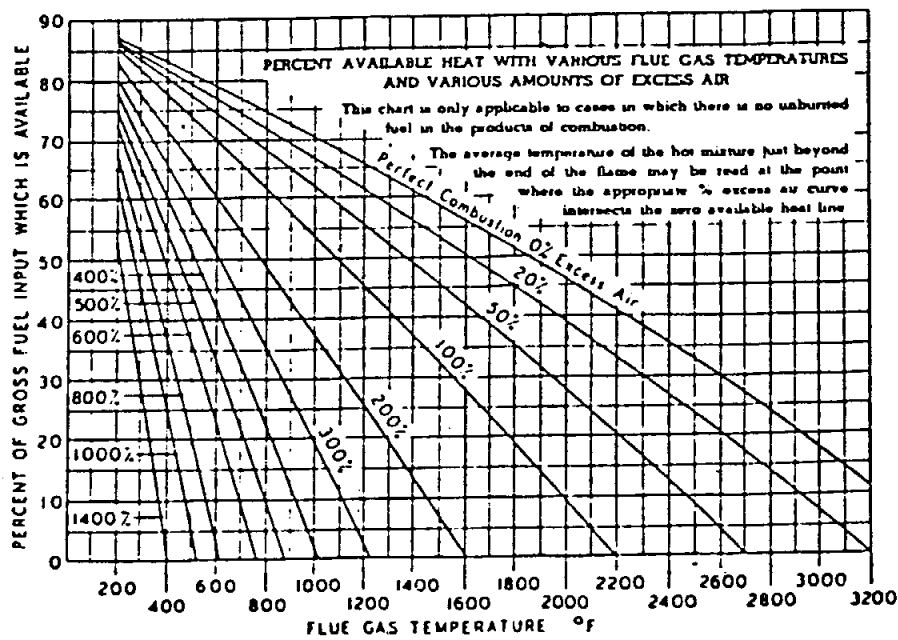


Figure No. 3

Example of use: With a flue gas temperature of 1100°F and an excess air requirement of 90%, the amount of heat available for metal melting (including heat lost by radiation) is approximately 52%.

Typical thermal properties of refractory and insulating concretes.

Aggregate.	Fired density, lb. per cub. ft.	Heat capacity, B.t.u. per (cub. ft.) (deg. F.)	Thermal conductivity, B.t.u. per (hr./sq. ft.) (deg. F. per in.)	Thermal diffusivity, (sq. ft. per hr.)
Vermiculite ..	35	9	1.2	0.011
Diatomite ..	55	14	1.7	0.010
Crushed H.T. insulating brick ..	85	21	3.2	0.013
Expanded clay ..	90	22	3.5	0.013
Crushed firebrick ..	115	29	6	0.017
Molochite ..	120	31	8	0.021
Sillimanite ..	135	33	10	0.025
Carborundum ..	145	40	50	0.103
Calcined bauxite ..	160	45	12	0.022
Magnesite ..	160	45	20	0.037
Chrome-magnesite ..	165	37	8	0.018
Fused magnesia ..	170	50	24	0.04
Fused alumina ..	175	52	16	0.026
Bubble alumina ..	95	22	6	0.023

TABLE - 1

Example of use: Read "K" (thermal conductivity) for type of lining in use.

PHYSICAL PROPERTIES*

	2100	2400	2600	2800	3000
Maximum Recommended Use Temperature	2100°F (1150°C)	2400°F (1315°C)	2600°F (1425°C)	2800°F (1540°C)	3000°F (1650°C)
Density (PCF)	12-15	18-22	18-22	18-22	18-22
Thermal Conductivity - k (BTU - In/S.F. - °F - Hr.)	Same k values for these compositions.				
Mean Temperature of					
600°F	0.26	0.29			
800°F	0.36	0.35			
1000°F	0.48	0.41			
1200°F	0.62	0.48			
1400°F	0.77	0.57			
1600°F	0.93	0.67			
1800°F	1.08	0.79			
2000°F	1.24	0.93			
2200°F	-	1.10			
2400°F	-	1.30			

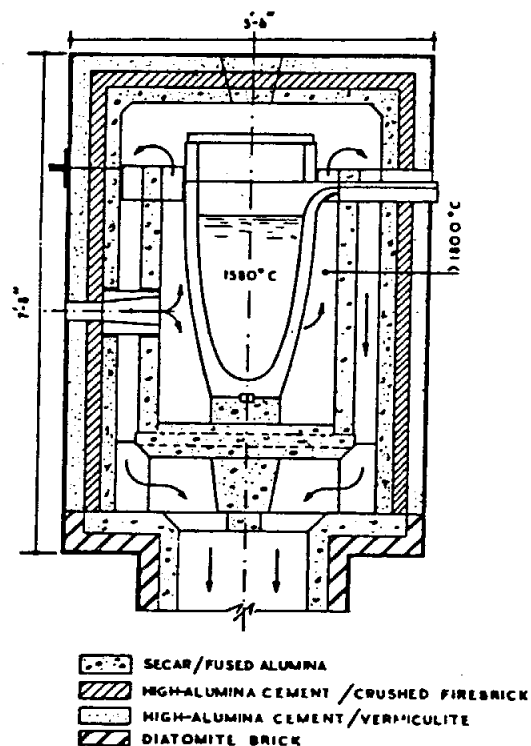
Ref. Industrial Insulations, Inc.

TABLE - 2

Example of use:

Determine mean temperature from formula; $\frac{t_1 - t_2}{2} = \text{Mean wall temp.}$

Read "K" thermal conductivity under maximum recommended use temperature.



Composite refractory- and insulating-
concrete lining of a propane-fired furnace

Figure No. 6

Example of K values for above material, refer to Fig. 4

Fused alumina,	K = 16
Crushed Firebrick,	K = 6
Vermiculite,	K = 1.2
Diatomite Brick,	K = 1.7

HEAT STORAGE AND LOSSES BTU/SQ. FT.

WALL THICKNESS	TYPE REFRACTORY	HOT FACE TEMPERATURE °F					
		1,200		1,600		2,000	
		H. ST.	H.L.	H. ST.	H.L.	H. ST.	H.L.
9"	Composite 2,000° insulation and firebrick	13,700	285	19,200	437	24,800	615
13-1/2"	Composite 2,000° insulation and firebrick	22,300	335	31,400	514	40,600	718
22-1/2"	Composite 2,000° insulation and firebrick	43,200	182	61,000	281	79,200	392
6"	Ceramic fiber	842	208	1,170	432	1,490	672

H. ST. - Heat Stored
H. L. - Heat Lost. BTU/Hr.

TABLE - 3

PREHEATING OF COMBUSTION AIR

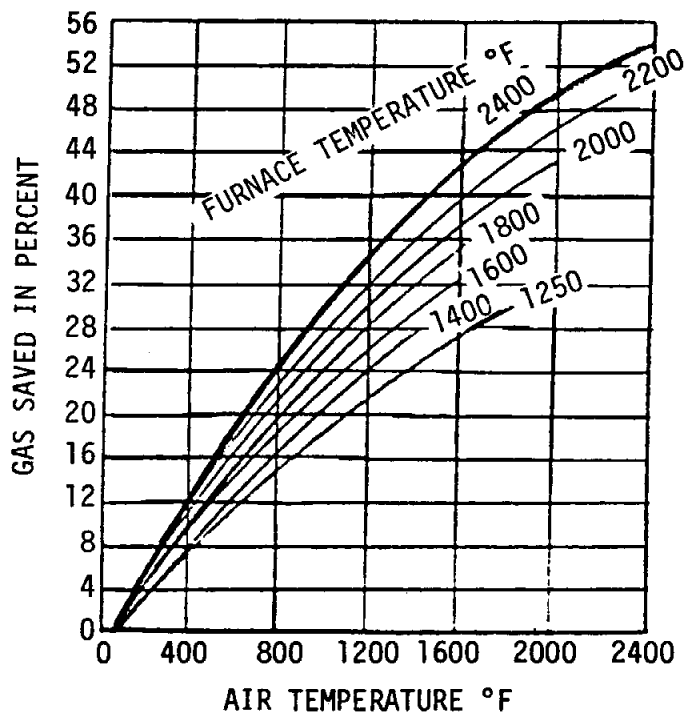


Figure No. 8

Example of use: Read gas saved in percent against furnace temperature curve for combustion air temperature obtained.

At 1600°F furnace temperature, and 1200°F air temperature, the gas saved is approx. 26 percent.

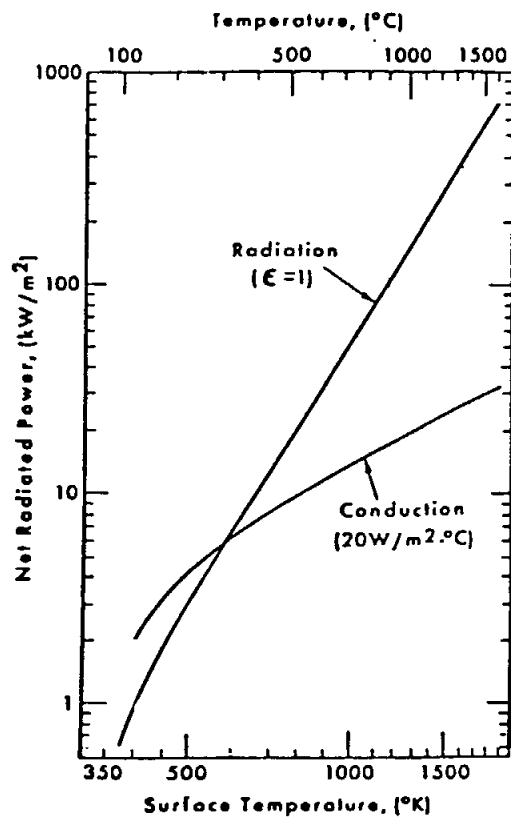


Figure No. 9

Example of use: Read net radiation (kW/m^2) against surface temperature and radiation curve.

e.g. at 800°C , radiated power is approx. 100 kW/m^2 .

Where $800^{\circ}\text{C} = 1472^{\circ}\text{F}$.

$100\text{ kW/m}^2 = 30,000\text{ BTU/sq.ft.}$

IMPROVING COMBUSTION EFFICIENCY

A crucible furnace melts 2,000 lbs of aluminum per hour, flow meter readings indicate that 3,500 cu. ft. of gas per hour (3.5×10^6 BTU/hr.) is used.

Flue gas temperature was measured at 1150°F and the flue gas analysis showed a CO_2 content of 5%. Find present combustion efficiency and probable efficiency, by installation of a nozzle mix burner and fuel/air ratio controls, if CO_2 content was corrected to 11% and excess air reduced to 10%. For this example it has been assumed that furnaces are equipped with covers.

Present Combustion Efficiency

Heat required to melt aluminum,

- Heat content of metal is 500 BTU/lb (Figure No. 1)
- Amount of metal heated per hour is 2,000lb.

Therefore, Heat to product is $500 \times 2000 = \underline{1,000,000 \text{ BTU/hr.}}$

Heat lost to exhaust.

- From Figure No. 2 with 5% CO_2 in flue gas the excess is approximately 130%.
- From Figure No. 3 with a flue gas temperature of 1150°F and 130% excess air, the percent of gross fuel input available to do work (including radiation losses) is approximately 40%.

Therefore, of the 3,500,000 BTU/hr. energy input only ($3,500,000 \times 0.4$) 1,400,000 BTU/hr (minus the radiation losses) is utilized.

Probable Combustion Efficiency

Heat lost to exhaust

- From Figure No. 2 with 11% CO_2 in flue gas the excess air is 10% approximately.
- From Figure No. 3 with a flue gas temperature of 1150° and 10% excess air, the percent of gross fuel input available to do work (including radiation losses) is approximately 65%.

Therefore, of the 3,500,000 BTU/hr. energy input ($3,500,000 \times 0.65$) 2,275,000 BTU/hr. is available for melting the metal.

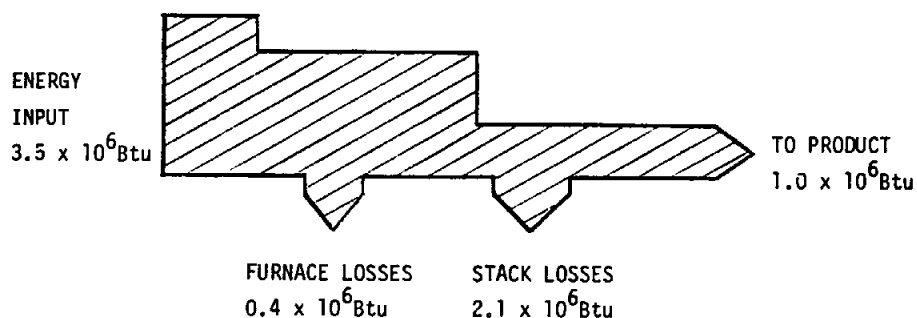
As previously stated the amount of heat required to melt 2,000 lbs. of aluminum is 1,000,000 BTU/hr. Present combustion efficiency calculations show that 1,400,000 BTU/hr. was available to melt the metal. Therefore: 1,400,000 - 1,000,000 results in 400,000 BTU/hr. being lost by radiation effects. By increasing the available fuel to 65% it can be readily seen that a smaller burner could be used to accomplish the same work.

$$\frac{875,000 \text{ BTU/hr.}}{350,000 \text{ BTU/hr.}} \times 100 = 25\% \text{ less fuel}$$

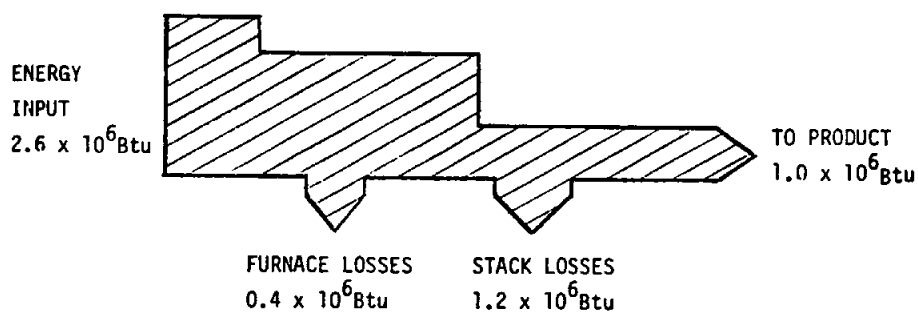
Summary

Item	Present Energy	Probable Energy
Heat to product	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Heatloss to Stack	2,100,000 BTU/hr.	1,225,000 BTU/hr.
Heatloss (Radiation)	400,000 BTU/hr.	400,000 BTU/hr.
Gross Input	3,500,000 BTU/hr.	2,625,000 BTU/hr.

Process Energy Flow Diagrams

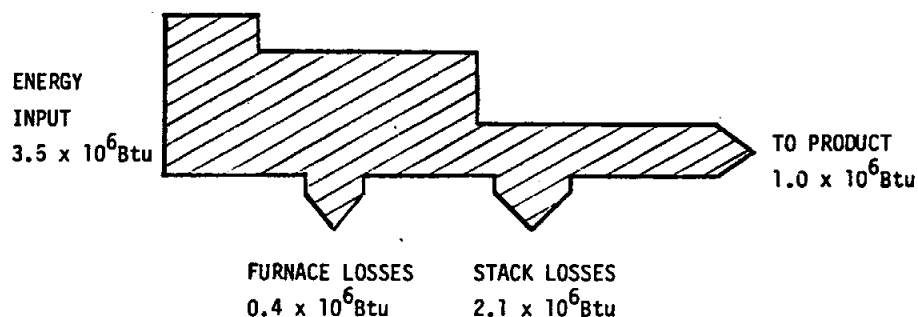


PRESENT CONDITION

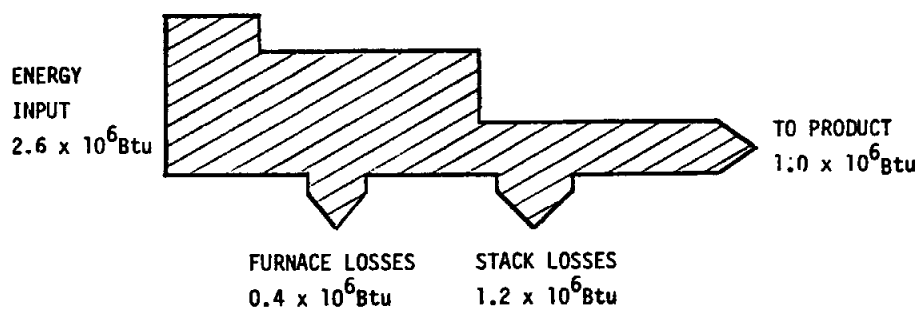


PROBABLE CONDITION

Process Energy Flow Diagrams



PRESENT CONDITION



PROBABLE CONDITION

Yearly Energy Cost Savings

Assuming, using the above example, that the furnace melted 8 hours per day, 5 days per week, 50 weeks per year then the energy and cost savings would be;

$8 \times 5 \times 50 \times 875,000 \text{ BTU/hr.} = 1750 \times 10^6 \text{ BTU}$ or 17500 therms/year,
at \$0.30 per therm, yearly savings would be \$5,250

COMBUSTION AIR PREHEATING

For typical gas fired furnace with flow rate of $3.5 \times 10^6 \text{ BTU/hr.}$, improved efficiency can be attained by preheating the combustion air with the use of a hot gas recuperator.

Example Calculations

With flue gas temperature of 1600°F, if combustion air is preheated to 1200°F, energy savings of approx. 26% are available as obtained from Fig. 8. Thus heat savings can be calculated for the typical gas fired furnace as follows:

$$2.625 \times 10^6 \text{ BTU/hr.} \times 0.26 = 0.68 \times 10^6 \text{ BTU/hr.}$$

Annual energy reduction based on 8 hours/day, 240 days per year is-

$$\frac{0.68 \times 10^6 \times 8 \times 240}{100,000 \text{ BTU/therm}} = 13,100 \text{ therms/yr. @ } \$0.3 \text{ per therm, cost reduction} = \underline{\$3,930/\text{year.}}$$

Summary

Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 Btu/hr.
Stack Losses*	1,225,000 BTU/hr.	545,000 BTU/hr.
Radiant Losses*	400,000 BTU/hr.	400,000 BTU/hr.
Gross Input	2,625,000 BTU/hr.	1,945,000 BTU/hr.

*Stack and radiant losses from previous example after improvements.

REFRACTORY MATERIALS - CRUCIBLE FURNACE

Sample Calculation -

A crucible furnace with composite refractory and insulating - concrete lining is compared to same furnace with ceramic fiber sleeve insulating material. Diagram of typical furnace with composite lining is shown in Fig. 6.

The heat loss through composite material is determined by calculation of "Q"

$$Q \text{ per sq. ft.} = \frac{t_1 - t_2}{R_1 + R_2} \text{ etc.}$$

Where t_1 = Hot Face Wall Temperature.
 t_2 = Cold Face Wall Temperature.
 R = Resistance, which is the wall thickness divided by "K", the conductivity of the material.

"K" for various materials is obtained from table of typical thermal properties Fig. 4. Thus $R_1 + R_2$ etc. for various thicknesses is:

$$R_1 = \frac{2}{16} (\text{fused alumina}) = 0.125$$

$$R_2 = \frac{3}{6} (\text{crushed firebrick}) = 0.333$$

$$R_3 = \frac{1}{1.2} (\text{vermiculite}) = 0.833$$

$$\text{Total } R_1 + R_2 + R_3 = 1.291$$

Area of side walls estimated to be 110 sq. ft.

Thus heat loss through composite material = Q_a

$$\therefore Q_a = \frac{(3,000 - 100) 110}{1.291} = 247,000 \text{ BTU/hr.}$$

NOTE: The above calculation demonstrates the methodology used for computing sample radiation losses. Actual radiation losses used throughout the preceding examples is 400,000 Btu/Hr.

Replace 6" composite material with 6" ceramic fiber sleeve of 3,000°F maximum use temperature. The calculation of mean temperature =

$$\frac{t_1 - t_2}{2} = \frac{3,000 - 100}{2} = 1450^\circ\text{F}$$

K value for mean temperature of 1450°F (from fig. 5) is prorated between 0.57 and 0.67 to be 0.60

$$\text{thus } R (\text{ceramic fiber}) = \frac{6}{0.60} = 10$$

Thus heat loss through ceramic fiber sleeve = Q_b .

$$\therefore Q_b = \frac{(3,000 - 100) 110}{10} = 31,900 \text{ BTU/hr}$$

$$\text{Change in heat loss } Q_a - Q_b = 247,000 - 31,900 = 215,100 \text{ BTU/hr}$$

Based on a melt program of 8 hours/day, 240 days per year, the annual gas usage reduction is as follows:

$$\frac{215,100 \text{ BTU/hr} \times 8 \times 240}{100,000 \text{ BTU/therm}} \times \$0.3 = \$1,240/\text{year.}$$

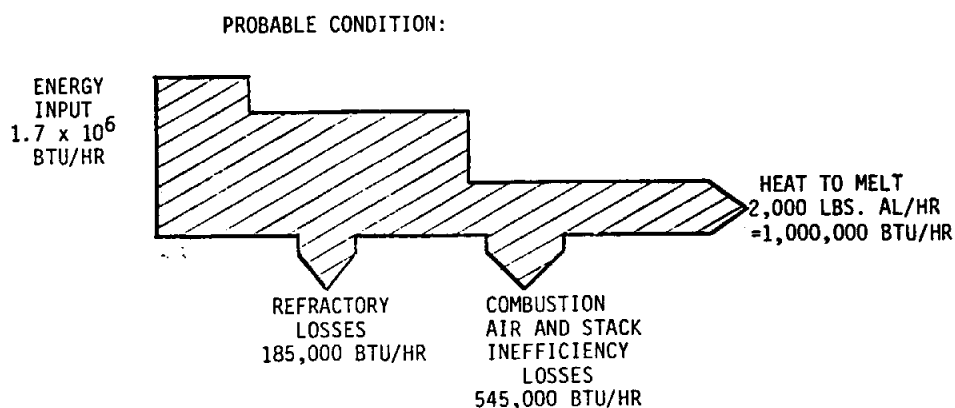
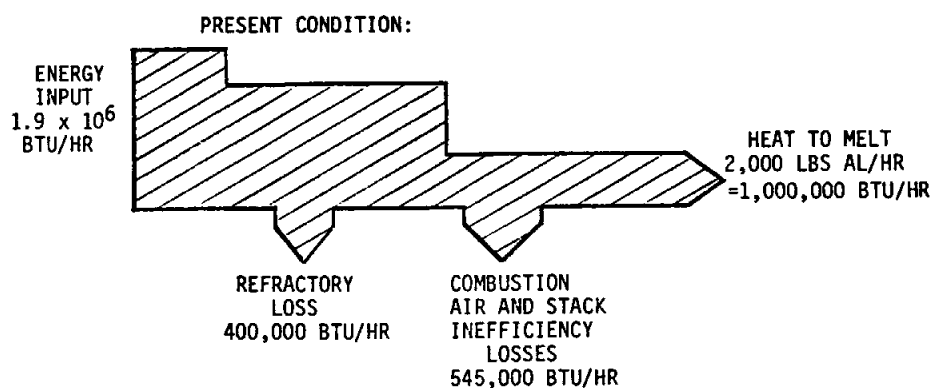
If original energy input is 1.945×10^6 BTU/hr., the furnace efficiency is improved from 51.4 per cent to approximately 57.8 percent, or 6.4% increase in efficiency.

Summary

Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Radiation loss*	400,000 BTU/hr.	185,000 BTU/hr.
Stack Loss*	545,000 BTU/hr.	545,000 BTU/hr.
Gross Input	1,945,000 BTU/hr.	1,730,000 BTU/hr.

* Stack and radiant losses from previous example after improvements of combustion equipment.

TYPICAL ENERGY FLOW DIAGRAM



FURNACE COVERS

Ladle and furnace covers eliminate most of the radiation loss which is the major area of energy loss from uncovered ladles and metal surfaces. Net radiated heat loss from a metal surface, emissivity, depends on the amount of slag. Emissivity of clean iron is relatively small but the thin slag layer usually present increases emissivity. Energy loss can be obtained by reference to Fig. 9 by reading net radiated power at metal temperature from the chart.

Example, at metal temperature of 800°C (1472°F), read for radiation at $E = 1$, net radiated power = 100 kw/m^2 ($0.03 \times 10^6 \text{ BTU/sq.ft.}$)

Where: $1 \text{ m}^2 = 10.76 \text{ sq.ft.}$

$1 \text{ kw} = 3412 \text{ BTU.}$

Sample Calculation-

Consider a gas fired furnace holding aluminum at 1400°F with dip well area 4 sq. ft. without a cover and calculate the energy savings with a ceramic fiber cover in place.

Radiation losses, at 1400°F (760°C) from Fig. 9 = 60 kw/m^2
= $19,000 \text{ BTU/sq. ft.}$

Thus $4 \text{ sq.ft.} \times 19,000 \text{ BTU} = 76,000 \text{ BTU/hr.}$

Heat loss from dip well with cover, based on thickness of two inches for ceramic fiber cover, is:

$$Q = \frac{t_1 - t_2}{R_1 + R_2} \text{ etc.}$$

where t_1 = hot face temp. 1400°F .

t_2 = cold face temp. 200°F .

R^2 = Resistance which is the thickness of the cover divided by the conductivity K .

K for cover material can be obtained from Fig. 5 where mean temperature of the material is given by

$$\text{Mean temp.} = \frac{t_1 - t_2}{2} = \frac{1400 - 200}{2} = 600^{\circ}\text{F}$$

Thus K from Fig. 5 at $600^{\circ}\text{F} = 0.26 \text{ (BTU/sq. ft. per ins. - }^{\circ}\text{F/hr.)}$

$$\therefore Q = \frac{(1400 - 200)}{2/0.26} 4 \text{ sq.ft.} = \frac{4800}{7.7} = 600 \text{ BTU/hr.}$$

Savings in energy loss = 76,000 - 600 = 75,400 BTU/hr.

With cover in place during 16 hours holding period per day, the reduction in energy for 240 days per year is:

$75,400 \times 16 \times 240 = 289 \times 10^6$ BTU/year @ \$0.3 per therm, the cost savings is:

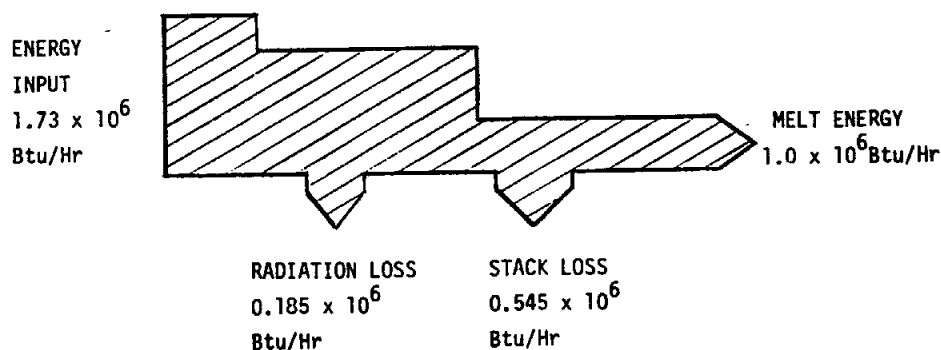
$$\frac{289 \times 10^6 \times 0.3}{100,000} = \underline{\$870 \text{ per year}}$$

Summary

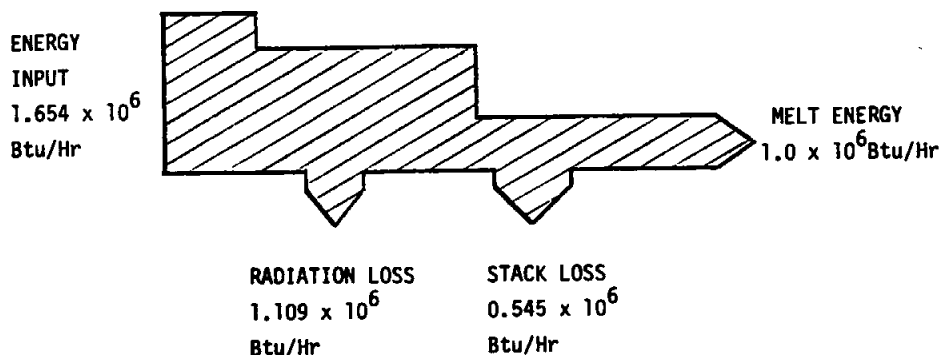
Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Radiation Loss*	185,000 BTU/hr.	109,600 BTU/hr.
Stack Loss*	545,000 BTU/hr.	545,000 BTU/hr.
Gross Input	1,730,000 BTU/hr.	1,654,600 BTU/hr.

*Stack losses and radiation loss from previous example for present conditions after improvements.

PRESENT CONDITION -



PROBABLE CONDITION -



OVERALL FURNACE EFFICIENCY

The following table summarizes the probable cost and energy savings by carrying out all of the possible improvements previously covered in the examples.

Summary (Energy and Cost Savings)

Item	BTU/hr. Reduction	Efficiency Percent Increase	Annual Gas Therms.	Savings Cost \$
Combustion Efficiency	875,000	25.0%	17500	5250
Preheat Comb. Air	680,000	26.0%	13100	3930
Refractory Upgrade	215,000	6.4%	4130	1240
Furnace Covers	75,000	2.6%	2900	870
Total	1,845,000	31.8	37,630	\$11,290

$$\text{Overall Thermal Efficiency} = \frac{1.0 \times 10^6}{(3.5 - 1.845) 10^6} \times 100 = 60.4\%$$

$$\text{Present Efficiency (Approximate)} = 28.6\%$$

$$\text{Increased Efficiency} = 60.4 - 28.6 = 31.8\%$$

$$\text{Percent Energy Saved} = \frac{1,845,000}{3,500,000} = 53\%$$

REVERBERATORY FURNACES

Energy savings and efficiency improvements can be developed for reverberatory furnaces. For combustion efficiency and burner preheating the previous examples are repeated and applied to reverberatory furnace summary analysis.

REFRACTORY MATERIALS - REVERBERATORY FURNACES

Sample Calculation-

Assume a reverberatory furnace melts 2,000 lbs of aluminum per hour. The area of refractory below metal is 40 sq. ft. and the area of refractory above metal is 40 sq.ft. Thickness of refractory is 6 inches. Metal is at 1380°F and combustion gas temperature above the metal is 3000°F. To find heat loss with conventional refractory, the thermal conductivity k for the material is determined from fig. 4 to be 6 BTU/hr. per sq. ft. (deg. F per inch.) for crushed firebrick.

$$\text{Heat loss } Q = \frac{t_1 - t_2}{R_1 + R_2} \text{ etc.}$$

Where t_1 = Hot face wall temperature
 t_2 = Cold face wall temperature
 R = Resistance, which is the thickness of the lining divided by the conductivity of the material K .

Mean temperature $\frac{t_1 - t_2}{2}$ is required to select K

Thus the mean temperature for area above the metal, based on a combustion gas temperature of 3000°F = $\frac{3000 - 100}{2} = 1450^\circ\text{F}$

Mean temperature for area below the metal = $\frac{1380 - 100}{2} = 690^\circ\text{F}$

$\therefore Q_a$ (above the metal) = $\frac{3000 - 100}{6/6} = 2900 \text{ BTU/Hr/Sq.Ft.}$

= $2900 \times 40 = 116,000 \text{ BTU/hr.}$

$\therefore Q_b$ (below the metal) = $\frac{1380 - 100}{6/6} = \frac{1280}{1} = 1280 \text{ BTU/hr/sq.ft.}$

= $1280 \times 40 = 51,200 \text{ BTU/hr.}$

\therefore Total heat loss through the refractory walls

= $Q_a + Q_b = 116,000 + 51,200 = \underline{167,200 \text{ BTU/hr.}}$

To find the heat loss with ceramic lining used for insulation between the refractory and the outer shell, the added R, resistance, must be calculated.

The thermal conductivity K for ceramic fiber is determined from Fig. 5 for 1 inch thick material to be 0.26 BTU/hr. per sq. ft. (deg. F per inch.)

Note - Mean temperature assumed between refractory and shell,
t = 200°F.

$$\begin{aligned} \therefore \text{New heat loss } Q_a + Q_b &= \frac{(t_{1a} - t_2) 40}{6/6 + 1/0.26} + \frac{(t_{1b} - t_2) 40}{6/6 + 1/0.26} \\ &= \frac{(3000 - 100) 40}{1 + 3.84} + \frac{(1380 - 100) 40}{1 + 3.84} = 23,970 + 10,600 \\ &= \underline{34,570 \text{ BTU/hr.}} \end{aligned}$$

Change in heat loss through lining by adding 1 inch of ceramic fiber insulation = 167,200 - 34,570 = 132,630 BTU/hr. reduction, equivalent to 79.3% saving.

Based on a melt program of 8 hours per day, 240 days per year, the annual gas cost reduction is as follows:

$$\frac{132,600 \text{ BTU/hr.} \times 8 \times 240}{100,000 \text{ BTU/therm}} \times \$0.3 = \underline{\$760}$$

Summary

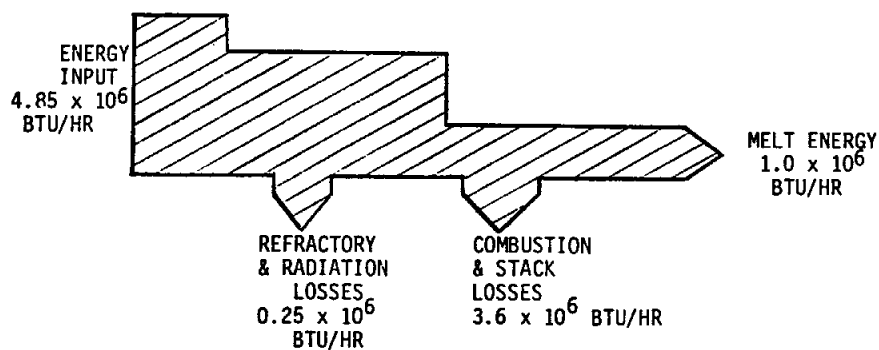
Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Radiation Losses*	250,000 BTU/hr.	117,000 BTU/hr.
Combustion and Stack Losses*	2,045,000 BTU/hr.	2,045,000 BTU/hr.
Gross Input	3,295,000 BTU/hr	3,162,000 BTU/hr.

* Combustion and stack losses from previous example after improvements are listed in this case for present energy use.

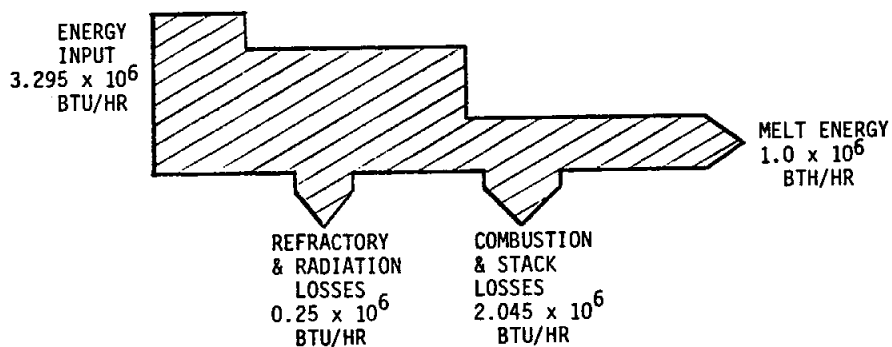
Energy flow diagrams for all improvements by progression from original condition to ultimate condition are as follows:

Energy Flow Diagrams - Reverberatory Furnace Example

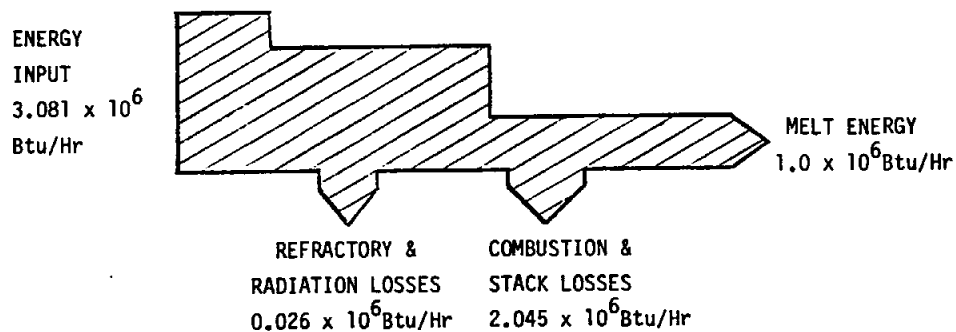
ORIGINAL CONDITION:



COMBUSTION IMPROVEMENT & BURNER AIR PRE-HEAT



REFRACTORY & METAL COVERS IMPROVEMENTS



OVERALL FURNACE EFFICIENCY

The following table summarizes the probable cost and energy saving available by carrying out all of the possible improvements in common with the crucible furnace per previous examples.

Summary (Energy and Cost Savings)

ITEM	BTU/HR REDUCTION	% ENERGY SAVING	ANNUAL GAS THERMS	SAVINGS COST \$
Combustion Efficiency*	875,000	25.0%	17,500	5,250
Preheat Combustion Air	680,000	26.0%	13,100	3,930
Refractory Upgrade	132,000	4.0%	2,550	760
Furnace Covers	75,000	2.1%	2,900	870
TOTAL	1,762,000		36,050	\$10,810

$$\text{Overall percent energy reduction} = \frac{1,762,000}{4,850,000} = 36.3\%$$

$$\text{Overall thermal efficiency} = \left(\frac{1.0 \times 10^6 \times 100}{4.85 - 1.762 \times 10^6} \right) = 32.3\%$$

$$\text{Present efficiency (approximate)} = 20.6\%$$

$$\text{Increased efficiency} = 32.3 - 20.6 = 11.7\%$$

ECONOMIC EVALUATIONCRUCIBLE
FURNACEREVERBERATORY
FURNACE

1. Replace existing burner system with a combination nozzle mix burner system-recuperator package with completely pre-wired control system Equipment Cost _____	\$ 30,000.00	30,000.00
2. Replace conventional refractory lining with ceramic fiber material _____	\$ 2,000.00	500.00
3. Metal covers in ceramic fiber material _____	\$ 200.00	200.00
4. Labor to install Item 1 _____	\$ 17,000.00	17,000.00
5. Engineering Costs _____	\$ 5,000.00	5,000.00
TOTAL	\$ 45,000.00	43,000.00

$$\text{Payback period} = \frac{\text{Capital Investment}}{\text{Energy Savings \$ / YR}} = \text{Years}$$

Therefore payback period (present day costs)

$$\text{Crucible Furnace} = \frac{45,000}{11,290} = 3.98 \text{ years}$$

$$\text{Reverberatory Furnace} = \frac{43,000}{10,850} = 3.98 \text{ years}$$

NOTE - The above costs are for example only, actual equipment costs are to be obtained for specific furnace item as part of normal engineering procedure. Labor costs for lining installations are assumed to be covered by normal maintenance expense budget.

HEAT TREATING

General Considerations

This section, dealing with the energy savings of the Heat Treat Furnace operation, will concentrate generally on the major areas for energy savings attributed to:

- Process operation and control
- Refractory materials
- Combustion equipment
- Heat recuperation

Formulas, calculations, and graphs have been simplified within the Scope of the Project from the normally complex task of calculating heat transfers, to reflect constant conditions during the process.

To investigate any process in depth it is essential to establish parameters, calculate the data and plot results on a continuous basis to establish the limits of the operation and equipment, and identify any trends.

The work sheet lists the expected parameters for furnace shell, blower, burner and ancillary equipment; and operational data to complete a "one shot" energy audit and constitute a base for any future improvements. A tape measure, thermometer, flue gas analyzer and flow meters will be the tools needed.

HEAT TREAT DATA INPUT

HEAT TREATING UNIT NO.1			
FURNACE MAKE <u>ANY</u>		BURNER MAKE <u>ABC</u>	
MODEL <u>ANY</u>		MODEL <u>ABC</u>	
SIZE <u>10' x 20' x 8' HIGH</u>		TYPE <u>Pre mix</u> SIZE <u> </u> BTU/HR	
CAPACITY <u>20,000</u> LBS.		FUEL <u>Natural Gas</u>	
TYPE OF LINING <u>Conventional</u>		RECUPERATOR MAKE <u>None</u>	
WALL THICKNESS <u>13½</u> INCH		MODEL <u>-</u> TEMP <u>-</u> °F	
BLOWER MAKE <u> </u>		TYPE <u>-</u> SIZE <u>-</u>	
MODEL <u> </u>		CONTROLS MAKE <u>None</u>	
SIZE <u> </u> CFM. PRESS <u> </u> "WG		TYPE <u>-</u>	
VOLT <u> </u> HP <u> </u>			
TYPE OF HEAT TREAT CYCLE <u> </u>		ALLOY <u> </u>	
HEAT TREAT CYCLE - HEATUP <u> </u> HRS		FUEL/AIR RATIO <u>Un-controlled</u>	
- SOAK <u> </u> HRS		HIGH LOW	
-COOL DOWN <u> </u> HRS		FLUE TEMPERATURE <u>1650</u> °F <u> </u> °F	
CYCLES PER WEEK <u> </u>		SHELL MEAN TEMPERATURE <u> </u> °F	
TEMPERATURE <u>1,650</u> °F		FURNACE PRESSURE <u>Negative</u> "WC	
AVERAGE LOAD <u> </u> LBS		FLUE ANALYSIS (HIGH) <u>N/A</u> % CO	
CASTING <u> </u> LBS		<u>N/A</u> % O ₂	
BASKETS <u> </u> LBS		<u>5</u> % CO ₂	
STOOLS <u> </u> LBS			
LOAD DENSITY <u> </u> LBS/WFT			
QUENCH <u> </u> AIR, <u> </u> H ₂ O <u> </u> OIL			
QUENCH TEMPERATURE <u> </u> °F		FUEL CONSUMPTION <u>116</u> THERMS/CYCLE	

MISCELLANEOUS

WALL AREA 880 SQ.FT.

WALL TEMPERATURE HOT FACE T₁ 1650 °F

WALL TEMPERATURE COLD FACE T₂ 160 °F

AMBIENT TEMPERATURE 80 °F

EXTERNAL SURFACE AREA 880 SQ.FT.

HOT SURFACE AREA 570 SQ.FT.

ENERGY COST/THERM \$ 0.30

HEAT TREAT LOADS/DAY

HEAT TREAT LOADS/YEAR

Note: Data Recorded is only that needed to perform sample calculations.

TABLES, GRAPHS AND CHARTS

Table I

APPROXIMATE THERMAL CONDUCTIVITIES OF FIRECLAY BRICK

Btu per Hour, per Square Foot, per Degree F. Temperature Difference,
for One-Inch Thickness

Kind of Brick	Den- sity*	Mean Conductivity at T°F.												
		200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600 2800
147	9.7	9.7	9.7	9.7	9.8	9.9	10.0	10.2	10.3	10.5	10.7	10.9	11.1	11.3
146	8.7	8.8	9.0	9.1	9.3	9.4	9.6	9.7	9.9	10.0	10.2	10.4	10.5	....
136	8.4	8.5	8.7	8.8	9.0	9.2	9.3	9.5	9.6	9.8	9.9	10.1	....	....
127	7.1	7.3	7.4	7.6	7.8	8.0	8.1	8.3	8.5	8.7	8.8	9.0	....	....
125	5.8	6.2	6.5	6.9	7.3	7.6	8.0	8.3	8.7	9.0	9.4	9.8	....	....

*Pounds per Cubic Foot.

NOTE: For brick of the same type, class, composition, and burn, the conductivities are approximately proportional to the bulk densities (weights in pounds per cubic foot).

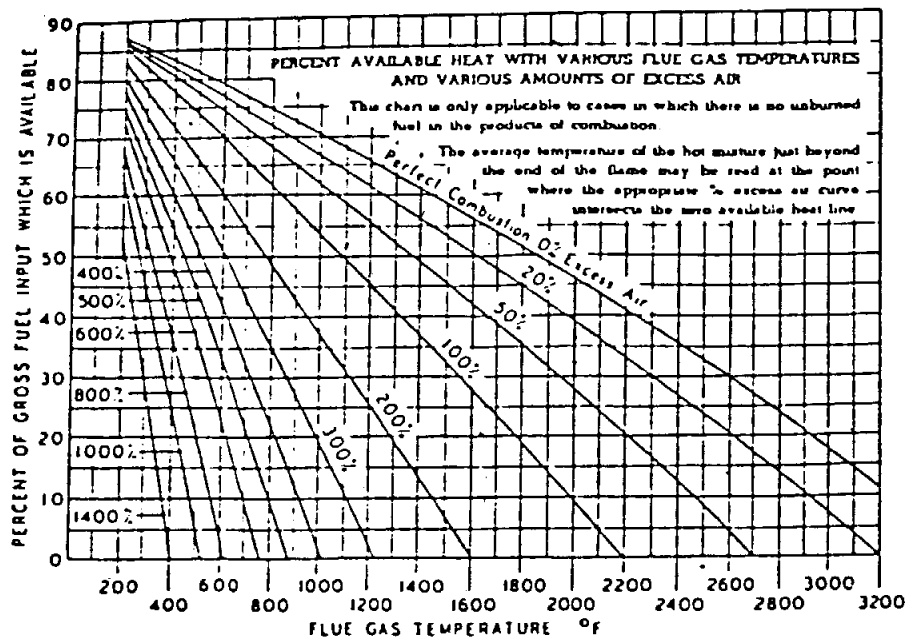
Table II

APPROXIMATE THERMAL CONDUCTIVITIES OF INSULATING FIREBRICK

Btu per Hour, per Square Foot, per Degree F. Temperature Difference,
for One-Inch Thickness

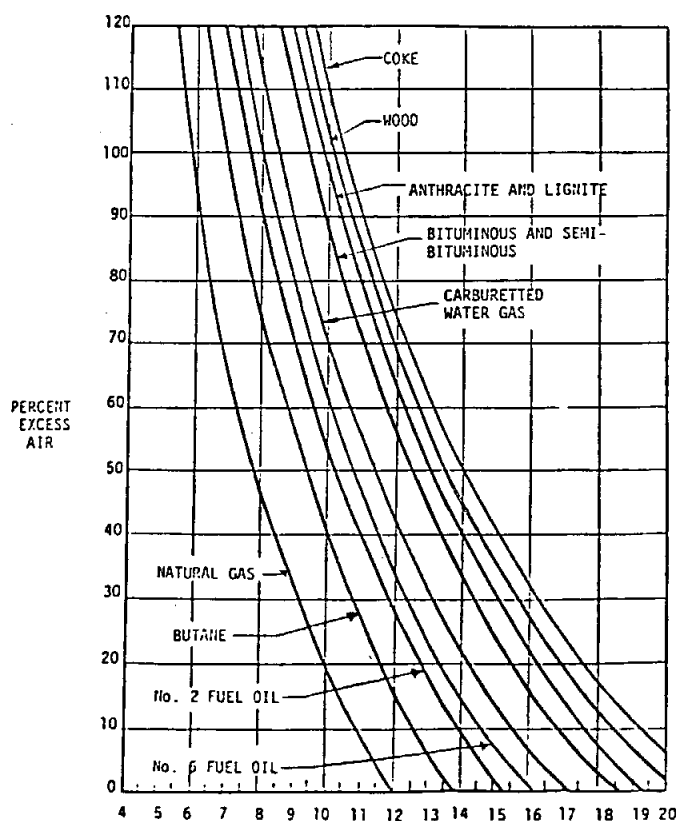
Den- sity*	Thermal Conductivity at T°F													
	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800
36	1.06	1.20	1.34	1.48	1.63	1.77	1.91	2.05	2.19	....	....	....	....	....
38	1.26	1.40	1.54	1.68	1.83	1.97	2.11	2.25	2.40	....	....	....	....	....
46	1.44	1.59	1.75	1.91	2.06	2.22	2.38	2.53	2.69	2.85	3.00	....	....	....
31	0.78	0.86	0.94	1.02	1.09	1.17	1.25	1.33	1.41	1.48	1.56	....	....	....
49	1.83	1.98	2.13	2.28	2.43	2.58	2.73	2.88	3.03	3.18	3.33	3.48	....	....
56	1.95	2.10	2.25	2.40	2.55	2.70	2.85	3.00	3.15	3.30	3.45	3.60	3.75	3.90
60	2.20	2.35	2.50	2.65	2.80	2.95	3.10	3.25	3.40	3.55	3.70	3.85	4.00	4.15

*Pounds per Cubic Foot



Example of use:
With a flue gas temperature of 1100 F and an excess air requirement of 90%, the amount of heat available (including heat loss by radiation) is approximately 52%.

FIGURE 1. PERCENT AVAILABLE HEAT*



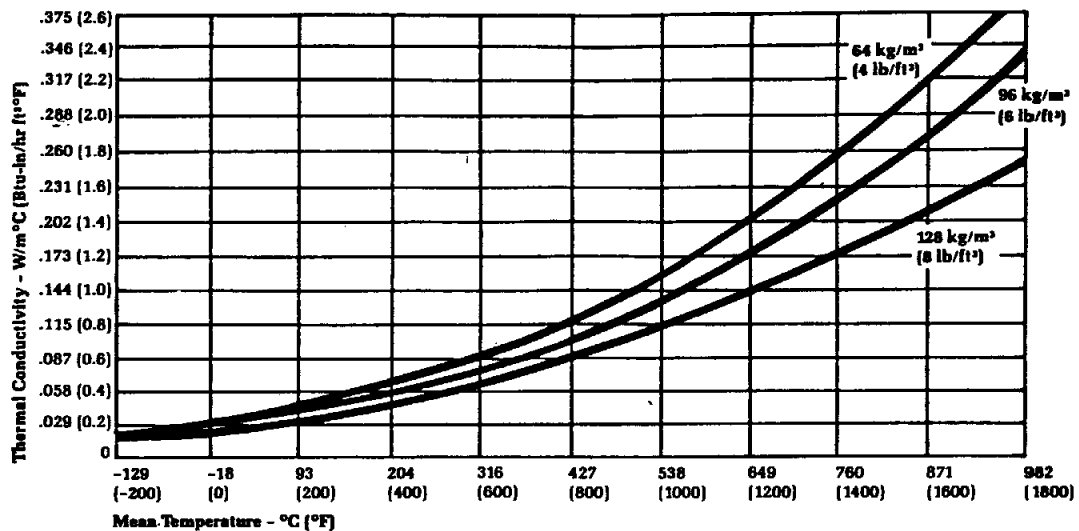
Example of Use: A combustion analysis shows 6% CO₂ content of the flue gas, with natural gas burning equipment the excess air is approximately 90%.

FIGURE 2. PERCENT EXCESS AIR FROM CO₂ READING*

*From North American Combustion Handbook

Table III CERAMIC FIBERS

Thermal Conductivity vs Mean Temperature (per ASTM C-177)**



**All heat flow calculations are based on a surface emissivity factor of .90, an ambient temperature of 27°C (80°F), and zero wind velocity, unless otherwise stated. All thermal conductivity values for Fiberfrax materials have been measured in accordance with ASTM Test Procedure C-177. When comparing similar data, it is advisable to check the validity of all thermal conductivity values and ensure the resulting heat flow calculations are based on the same condition factors. Variations in any of these factors will result in significant differences in the calculated data.

Heat storage and losses can be approximated based on the following Table IV.

Table IV HEAT STORAGE AND LOSSES BTU/SQ. FT.

Table IV
HEAT STORAGE AND LOSSES BTU/SQ. FT.

WALL THICKNESS	TYPE REFRACTORY	HOT FACT TEMPERATURE °F					
		1,200		1,600		2,000	
		H. ST.	H. L.	H. ST.	H. L.	H. ST.	H. L.
9"	Composite 2,000° insulation and firebrick	13,700	285	19,200	437	24,800	615
13-1/2"	Composite 2,000° insulation and firebrick	22,300	335	31,400	514	40,600	718
22-1/2"	Composite 2,000° insulation and firebrick	43,200	182	61,000	281	79,200	392
6"	Ceramic fiber	842	208	1,170	432	1,490	672

H. ST. - Heat Stored
H. L. - Heat Lost Btu/hr

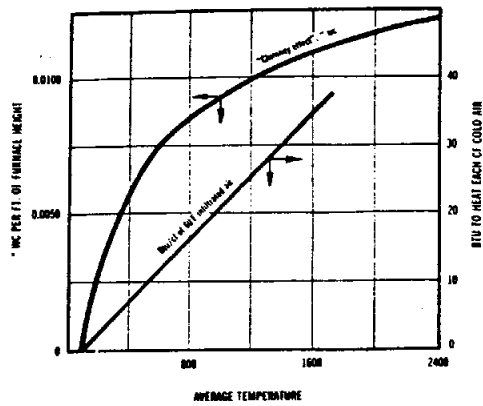


FIGURE 3A

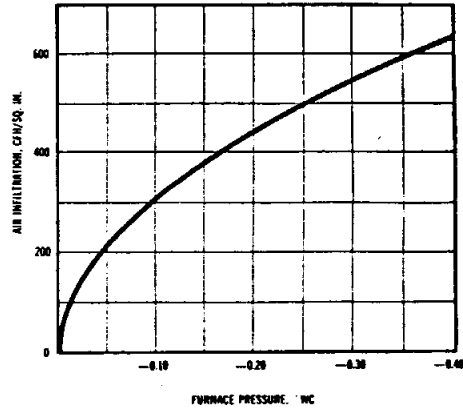


FIGURE 3B

Courtesy of American Gas Association

Above table to be used for calculating air infiltration through cracks.

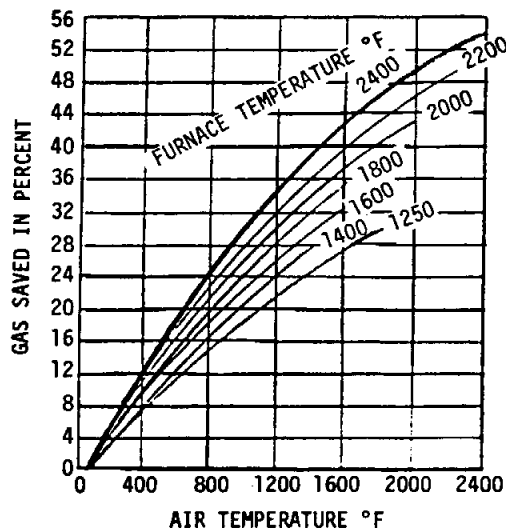


FIGURE 4. Preheating of Combustion Air*

*From AGA Catalog

SAMPLE CALCULATIONS (Energy Related)

Upgrading Furnace Linings.

Heat loss through various refractory linings can be calculated by the use of the following mathematical formula:

$$\text{HEAT LOSS "Q"} = \frac{t_1 - t_2}{R_1 + R_2} \text{ etc.}$$

WHERE:

t_1 = Hot face wall temperature

t_2 = Cold face wall temperature

R = Resistance, which is the thickness of the lining divided by the conductivity of the material "K"

Typical values of "K", thermal conductivity in Btu/hr, per square foot, per degree "F" temperature difference, for one inch thickness are listed in Tables I and II for fire clay and brick refractories.

"K" values for ceramic fiber linings are shown in Table III.

The heat required to get refractories up to furnace operating temperature (heat storage effect) is listed in Table IV.

To obtain "K" factors from Tables I, II, and III it is necessary to calculate the mean temperature. This is accomplished by adding t_1 and t_2 and dividing by 2. Thus mean temperature for this set of conditions is:

$$\frac{1650^{\circ}\text{F} - 160^{\circ}\text{F}}{2} = 905^{\circ}\text{F.}$$

Example: Determine heat loss through furnace walls lined with:

- (a) Conventional brick refractory lining
- (b) Laminated ceramic lining
- (c) Full ceramic fiber lining

(a) Conventional refractory lining is composed of the following materials:

- 9" fire brick with a density of 147 lbs/cu. ft.
- 4-1/2" insulated brick with a density of 31 lbs/cu. ft.

Therefore:

$$\text{Heat Loss} = \frac{1650 - 160}{.91 + 4.24} = 289 \text{ Btu/hr/F}^2$$

1/ To find resistance "R" for insulated brick, enter Table II at 905°F (mean temperature) and read down to the 31 lb. density column, the resultant "K" factor is approximately 1.06,

$$\text{therefore } R = \frac{4-1/2}{1.06} = 4.24$$

Total heat loss through furnace walls:

$$= 289 \text{ Btu/hr/ft}^2 \times 570 \text{ Sq. ft.} = \underline{164,730 \text{ Btu/Hr.}}$$

(b) Laminated refractory lining is composed of:

- 9" fire brick with a density of 147 lb/cu. ft.
- 4-1/2" insulated brick, density of 31 lbs/cu. ft.
- 1" ceramic fiber lining, density of 8 lb/cu. ft.

Therefore:

$$\text{Heat Loss} = \frac{1650 - 160}{.91 + 4.24 + 1.43} = 226 \text{ Btu/hr/F}^2$$

Total heat loss through furnace walls:

$$= 226 \text{ Btu/Hr/F}^2 \times 570 \text{ Sq. Ft.} = \underline{128,820 \text{ Btu/hr.}}$$

(c) Full ceramic fiber lining, composed of the following:

- 12" ceramic fiber at 8 lbs. density/cu. ft.

Therefore:

$$\text{Heat Loss} = \frac{1650 - 160}{17.14} = 87 \text{ Btu/hr/F}^2$$

2/ To find resistance "R" for ceramic fiber, enter Table III at 905°F., extend up to the 8 lb. density column and read 0.7 at the left hand side of the graph, therefore:

$$R = \frac{12}{0.7} = 17.14$$

Total heat loss through furnace walls:

$$= 87 \text{ Btu/hr/Ft}^2 \times 570 \text{ Sq. Ft.} = \underline{49,590 \text{ Btu/hr.}}$$

Summary - Heat Loss for Various Linings

ITEM	Btu/hr	% Savings over Basic Refract.
Conventional Refractory	164,730	-0-
Laminated Refractory	128,820	22%
Ceramic Fiber	49,590	70%

Equivalent total gas usage reduction, utilizing ceramic fiber lining, is $164,730 - 49,590 = 115,140 \text{ Btu/hr}$ or 1.15 Therms per hour.

Based on a continuous heat treat operation (with furnace in equilibrium) of 16 hours per day, 5 days per week-50 weeks per year, the total yearly gas savings would be as follows:

$$\frac{115,140 \text{ Btu/Hr} \times 16 \times 5 \times 50}{100,000 \text{ Btu/Therm}} \times \$0.3 = \underline{\$1,382.00 \text{ per year}}$$

Batch type heat treat operation is very costly in terms of gas usage due to the input energy required to heat the refractory mass up to furnace operating temperature, the following table illustrates the amount of energy required to heat the refractory to 1,600°F. versus that required for ceramic fiber:

ITEM	1/Heat Capacity Stored - Btu	% Savings over Basic Refractory
Conv. Refractory (13-1/2")	17,898,000	
Ceramic fiber (12")	1,333,800	92.5%

1/ Based on 570 sq. ft. inside furnace area and heat storage figures from Table IV.

Operating batch furnaces on a rapid change-over schedule will realize substantial fuel savings, also consideration must be given to the product to be processed. The scheduling effort to load to design capacity will be more than offset by the fuel savings obtained by reduced heating of the lining.

Quantative figures for overall savings, as a percentage of gas input to furnace, for upgrading conventional lining cannot be stated due to the many variables encountered in actual heat treat practices as applied to individual foundry operations. Savings shown in the example calculations, for lining replacements is attributed to radiation loss savings only.

Improving Combustion Efficiency.

A Heat Treat Furnace has the following characteristics (from input data sheet):

- Furnace size: 20' x 10' x 8 ft. high.
- Furnace capacity: 20,000 Lbs.
- Operating temperature: 1,650°F.
- 5% CO₂ in flue gas.
- Flue gas temperature: 1,650°F.
- Natural gas flow rate: 116 Therms/Hr. or 11,600 cu. ft.
- Furnace physical condition: 1/4" crack visible all around door.

Calculate present combustion and furnace efficiency and probable furnace efficiencies if the furnace was upgraded as follows:

- Install nozzle mix burners with flue/air ratio controls.
- Install furnace pressure controls.
- Install hot gas recuperator for preheating combustion air.
- Repair furnace door and seal cracks.

Example No. 1: Calculate present excess air and available heat.

Excess air through burner system with 5% CO₂ in flue gas (from Figure 2) is 130%.

Therefore, available heat to do work, (from Figure 1) with 130% excess air and 1,650°F. flue gas temperature, is 20% of 11,600 cu. ft./Hr of natural gas which is:

$$11,600 \text{ cu. ft./Hr} \times 0.20 = 2,320 \text{ cu. ft./Hr or } 2,320,000 \text{ Btu/Hr}$$

Example No. 2: Calculate secondary excess air infiltration due to door leakage.

From Table 3A with an average furnace temperature of 1,650°F., the furnace negative pressure due to chimney effect is 0.011" WC per foot of furnace height.

Therefore, total negative pressure is $0.011 \times 8 = 0.088''$ WC.

From Table 3B with a total furnace negative pressure of 0.088, the air infiltration is approximately 280 cubic feet per hour per square inch of crack opening.

Therefore, total crack opening is, based on 28 linear feet of door circumference, $336 \text{ inches} \times 1/4'' = 84 \text{ sq. inches}$.

From Table 3A with an average furnace temperature of $1,650^{\circ}\text{F.}$, approximately 35 Btu is necessary to heat each cubic foot of infiltrated air, therefore, total heat required is:

$$35 \text{ Btu} \times 84 \text{ sq. inches} \times 280 \text{ cu. ft./Hr/Sq. inch} = 823,200 \text{ Btu/Hr.}$$

Present Combustion Efficiency.

From Example 1. Available Heat = 2,320,000 Btu/hr.

From Example 2. Heat Lost (Infiltration) = 823,200 Btu/hr.

Net Heat Available = 1,496,800 Btu/hr

$$\text{Efficiency} = \frac{1,496,800}{11,600,000} \times 100 = 12.9\%$$

Example No. 3: Calculate probably combustion efficiency after installing new burner system and sealing furnace cracks. CO_2 content corrected to 11% and positive pressure maintained in furnace.

Available heat to do work (from Table 1) with 10%.

Excess air is $53\% \times 11,600,000 \text{ Btu/hr} = 6,148,000 \text{ Btu/hr}$

Net increase in heat content available is:

$$6,148,000 \text{ Btu/hr} - 1,496,800 \text{ Btu/hr} = 4,651,200 \text{ Btu/hr}$$

or 75.65% increase

Based on 5 days per week, 50 weeks per year heat treat operation with heat-up time averaging 6 hours, the yearly energy savings would amount to:

$$\frac{4,651,200 \text{ Btu/hr} \times 5 \times 50 \times 6}{100,000 \text{ Btu/Therm}} = 69,000 \text{ Therms per year.}$$

At \$0.3 per therms, dollar savings would be \$20,700/year

Combustion Air Preheating

From the preceding examples approximately 5,452,000 Btu/hr (11,600,000 - 6,148,000) is lost through the exhaust stack and radiation losses through the furnace walls. By preheating the combustion air with the use of a hot gas recuperation, the following additional energy savings can be realized

Example No. 4: With flue gas temperature of 1650°F, calculate the energy savings if combustion air is preheated to 1200°F.

From figure No. 4 the resultant fuel savings will amount to approximately 28%.

Therefore; additional heat saved per hour

$$= 0.28 \times 11,600,000 \text{ Btu/hr} = 3,248,000 \text{ Btu/hr}$$

Annual energy saving, using same operating time as stated in example 3, is:

$$\frac{3,248,000 \text{ Btu/hr} \times 1,500 \text{ Hrs.}}{100,000 \text{ Btu/Therm}} = 48,000 \text{ Therm/yr}$$

At \$0.3 per therm, dollar savings would amount to \$14,400

Overall Furnace Efficiency

The following table summarizes the possible cost and energy savings by upgrading existing furnace.

Item	Btu/hr Saved	ENERGY SAVINGS PERCENT	Annual Gas Savings	
			Gas (Therms)	Cost
Furnace Radiation Losses	115,140	70%	4,600	\$1,382
Improve Comb. Efficiency	4,651,000	53%	69,000	\$20,700
Pre-heat Combustion Air	3,248,000	28%	48,000	\$14,400
Total	8,014,140		121,600	\$36,482

$$\text{Overall Energy Savings} = \frac{8,014,140}{11,600,000} \times 100 = 69\%$$

Note: The foundry industry, in general, is experiencing between 50 to 60% actual Energy Savings by upgrading their present heat treat furnaces. Energy calculations in Section III of this study are based on 56% savings.

Summary

It must be restated that this analysis has been oversimplified to illustrate the need for improving existing thermal efficiency. The examples used can be a valuable tool in estimating potential savings. A full heat balance and thermal analysis should be made by an expert in this field before a major conversion is made. The energy savings are there if product requirements can be adjusted toward that goal.

Economical Evaluation

- (a) Replace existing burner system with a combination nozzle mix Burner system - recuperator package with completely pre-wired control system. (Equipment Cost).....\$90,000
- (b) Replace conventional refractory lining with 12" thick ceramic fiber insulation - material cost.....\$15,000
- (c) Labor to install item No. 1*.....\$40,000
- (d) Engineering costs.....\$10,000
- Total.....\$155,000

$$\text{Pay Back Period} = \frac{\text{Capital Investment}}{\text{Energy Savings Cost}} = \text{___ yrs.}$$

$$\text{Therefore: Pay Back} = \frac{\$155,000}{36,482} = 4.25 \text{ years}$$

The above pay back period does not take into account future cost of natural gas which could increase as high as 15% per year, or government tax credits for installation of energy saving devices.

*Installation labor does not include the relining of the furnace. It is assumed that this labor would be performed by foundry maintenance personnel and expensed.

LADLE HEATING

General

Ladle Heating is a very necessary requirement in any castmetal operation, it is a large user of natural gas and is probably the greatest abuse of gas energy in foundries today. This Section will examine the requirements for upgrading or replacing existing equipment for ladle drying and heating, covering the following:

- Ladle covers
- Burner efficiencies
- Improved insulation

Formulas, calculations, and graphs have been simplified within the scope of the project from the normally complex task of calculating heat transfers, to reflect constant conditions during the process.

To investigate any process in depth it is essential to establish parameters, calculate the data and plot results on a continuous basis to establish the limits of the operation and equipment, and identify any trends.

OPERATIONAL DATA FACT SHEET

LADLE PREHEAT DATA

LADLE CAP TONS 1.0 HEAT CYCLES/DAY 3
LADLE AREA INSIDE 12 SQ FT. LINING THICKNESS 2.5 ins.
COVERED No TYPE OF LINING Firebrick
INSIDE TEMP 1560 °F OUTER SHELL TEMP 300 °F
AMBIENT TEMP N/A °F
GAS USAGE/HR 550 CU FT. CO₂ READING N/A
COMBUSTION AIR N/A CFM PRESSURE -- WG
PREHEAT CYCLE TIME 1.0 HRS FLUE TEMP -- °F
REFRACTORY K VALUE 6 RS VALUE 0.33
BLOWER HP N/A RECUPERATOR EFFCY --
FUEL COST/THERM \$ 0.3 ANNUAL USE N/A BTU x 10⁶
NUMBER OF UNITS IN USE 1

GRAPHS, TABLES AND CHARTS

Figure 1 shows typical relationship of time versus temperature to fuel input for uncovered and covered ladles both with tight fitting and raised covers.

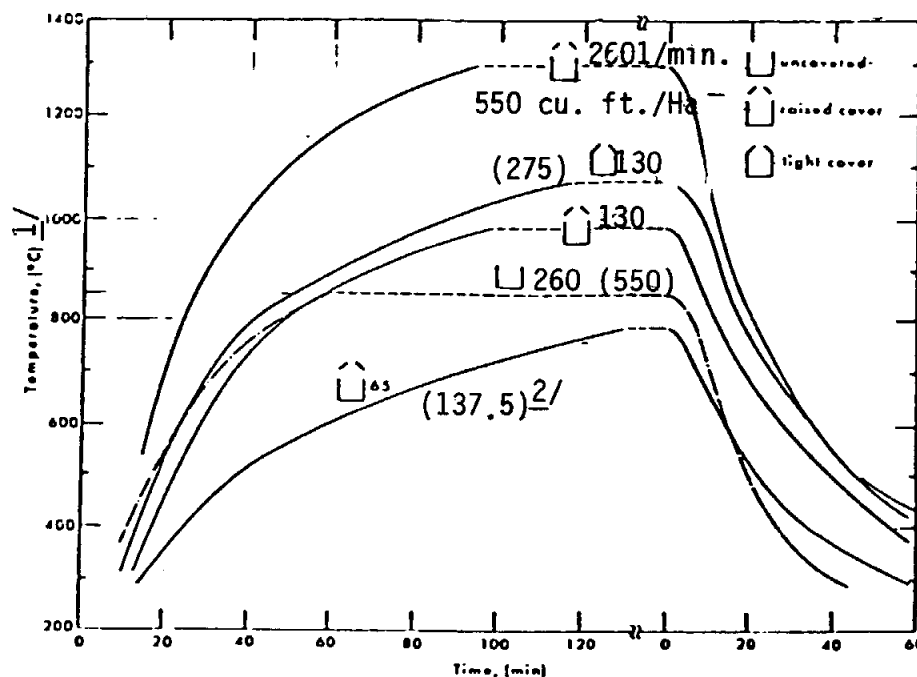


Figure No. 1

- 1/ Temperatures both in °C and °F at the inside bottom of the ladle.
- 2/ Figures shown are gas flow rates in liters per min. and cubic feet per hour.

Example of use: Curve is developed for specific ladle size with measured gas flow rates.

Read elapse time from intersection of curve with temperature.

For covered ladle at 275 cu. ft./hour gas flow, the time to attain required temperature 850°C, is approximately 50 minutes.

Figure 2

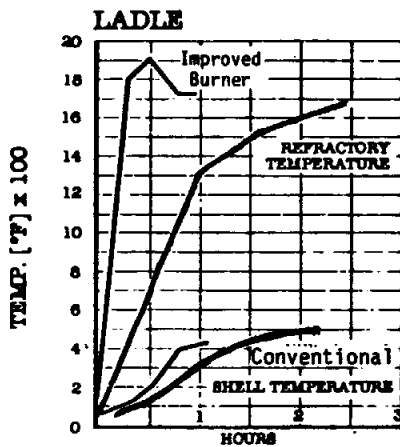
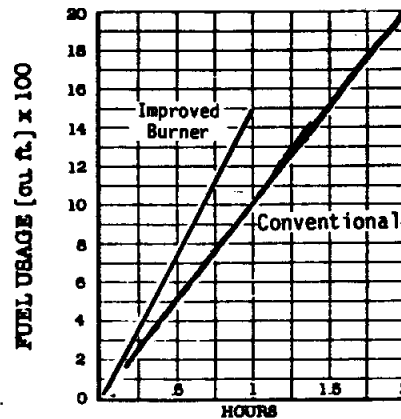


Figure 3



Reference: Hotwork Mfg. Inc.

Example of use:

Figure 2: Read elapsed time hours at intersection of temperature with improved burner graph line; then,

Figure 3: Obtain fuel usage for improved burner by reading up from elapsed hours to intersection with graph line and across to fuel usage.

For example: At temperature requirement of 1300°F, read approximately 0.25 hours (for improved burner) from Figure 2.

Transfer hours (0.25) onto Figure 3 and read approximately 400 cu. ft. fuel used by improved burner.

Table 1

8 - Typical Thermal Properties of Refractory and Insulating Concretes (Mix proportions approx. 1 vol. cement: 3 - 4 vols. aggregate).

Aggregate.	Fired density, lb. per cub. ft.	Heat capacity, B.t.u. per (cub. ft.) (deg. F.)	Thermal conductivity, B.t.u. per (hr./sq. ft.) (deg. F. per in.)	Thermal diffusivity, (sq. ft. per hr.)
Vermiculite	35	9	1.2	0.011
Diatomite	55	14	1.7	0.010
Crushed M.T. insulating brick	85	21	3.2	0.013
Expanded clay	90	22	3.5	0.013
Crushed firebrick	115	29	6	0.017
Molochite	120	31	8	0.021
Sillimanite	135	33	10	0.025
Carborundum	145	40	50	0.103
Calcined bauxite	160	45	12	0.022
Magnesite	160	45	20	0.037
Chromite-magnesite	165	37	8	0.013
Fused magnesia	170	50	24	0.04
Fused alumina	175	52	16	0.026
Bubble alumina	95	22	6	0.023

Thermal Conductivity

(Table 2)

	2100	2400	2600	2800	3000
Maximum Recommended Use Temperature	2100°F (1150°C)	2400°F (1315°C)	2600°F (1425°C)	2800°F (1540°C)	3000°F (1650°C)
Density (PCF)	12-15	18-22	18-22	18-22	18-22
Thermal Conductivity - k (BTU · In./S.F. · °F · Hr.)	<p>Same k values for these compositions.</p> <p>"k" measurements made at Refractories Research Center, Ohio State University.</p>				
Mean Temperature °F					
600°F					
800°F					
1000°F					
1200°F					
1400°F					
1600°F					
1800°F					
2000°F					
2200°F					
2400°F					

* Ref. Industrial Insulations Inc.

SAMPLE CALCULATIONS (Energy Related)

LADLE COVERS:

Heat loss during pre-heat of ladle relates to time in attaining required temperature measured at the inside bottom of the ladle.

Typical burner sizes for average ladle capacities of 1 ton (iron) is 1.0×10^6 Btu/hr. Therefore energy savings for any capacity ladle can be pro-rated based on pre-heat time for any size burner.

Example:

Burner size 1" (1.0×10^6 Btu/hr) shows a gas flow rate of 275 cu.ft./hr.

The elapsed time to attain 850°C (1560°F) with the tight-cover ladle, is approximately 50 minutes, reference Figure 1.

$$\text{Thus gas usage} = \frac{50}{60} \times 275,000 = 0.230 \times 10^6 \text{ Btu}$$

The elapsed time to attain 850°C (1560°F) with a raised cover ladle utilizing gas flow rate of 275 cu.ft./hr, is approximately 50 minutes, reference Figure 1.

$$\text{Thus gas usage} = \frac{60}{60} \times 275,000 = 0.275 \times 10^6 \text{ Btu}$$

The elapsed time to attain 850°C (1560°F) with an open ladle utilizing gas flow rate of 550 cu.ft./hr is approximately 60 minutes, reference Figure 1.

$$\text{Thus gas usage} = \frac{60}{60} \times 550,000 = 0.55 \times 10^6 \text{ Btu}$$

Relative savings for the alternate arrangements is:

Item	Btu's	Change in energy
Uncovered ladle	550,000	-0-
Raised cover ladle	275,000	- 50.0%
Tight cover ladle	230,000	- 58.0%

In quantitative terms the covered ladle (tight cover) results in gas usage reduction of:

$$550,000 \times 0.58 = 320,000 \text{ Btu/hr}$$

$$\text{At } \$0.3 \text{ per therm, cost reduction} = \$0.96/\text{hr}$$

Based on 20 % utilization, 8 hours/day, 240 days per year, the annual cost reductions:

$$0.96 \times 8 \times 240 \times 0.2 = \$370$$

It should be noted that the example is worked for one ladle only whereas generally more than one ladle is in use daily. Also size of ladle and therefore burner size will have impact on total possible savings.

COMBUSTION SYSTEMS

High efficiency burners reduce drying and preheating time which translates into increased ladle utilization and energy reduction.

Comparison between a conventional burner (high intensity) and a high efficiency burner is shown in Figure 2 and Figure 3.

Example: Time required to raise ladle refractory to 1300°F is 1 hour, using conventional burner.

Indicated time for improved burner with high efficiency characteristics, is shown on Figure 2 to be approximately 0.25 hours. With fuel usage of 1,000 cu. ft. and 400 cu. ft. respectively as indicated on Figure 3.

Thus efficiency improvement is calculated from

$$\frac{\text{Fuel usage reduction} \times 100}{\text{Original fuel usage}} = \text{percent}$$

$$\text{Therefore: } \frac{(1,000 - 400) 100}{1,000} = 60.0\%$$

Equivalent energy reduction for ladle preheating in previous example using 230,000 Btu/hr, the gas usage reduction is:

$$230,000 \times 0.60 = 138,000 \text{ Btu/hr.}$$

At \$0.3 per therm, the cost reduction =

$$\frac{138,000 \text{ Btu/hr} \times 0.3}{100,000 \text{ Btu/Therm}} = \$0.414/\text{hr}$$

Based on 20 % utilization, 8 hours/day, 240 days per year, the annual cost reduction is:

$$\$0.414 \times 8 \times 240 \times 0.2 = \$160$$

INSULATION

Ladle insulation and covers increases heating efficiency which leads to quicker heating and thus less time for losing energy by conduction and radiation through the ladle walls. Improved wall insulation saves energy in two ways, first by reduction in pre-heat gas requirements and second by minimizing the metal temperature loss during the pour, thus lowering the initial superheat required by the melter and extending the usable pouring period of the ladle with the possibility of reducing scrap castings by pouring less cold metal.

Example of energy savings by installing 1/2 inch insulation between the 2 inch refractory and the shell. The heat lost during ladle preheating is to be calculated and compared to lining without insulation.

Area of lining 30" dia. x 30" deep = 12 sq. ft.

Heat loss through conventional lining material is calculated from

$$Q = \frac{t_1 - t_2}{R_1 + R_2} = \text{Btu/Sq.Ft/hr}$$

Where $R = \frac{\text{Thickness of Lining}}{\text{"K" value}}$

t_1 = hot face temperature (1300°F)

t_2 = cold face temperature (200°F)

K = thermal conductivity of lining material from Figure 4 and Figure 5

$$\text{Thus } Q_a (\text{no insulation}) = \frac{(1300 - 200)}{R_1} 12 \text{ sq.ft.}$$

$$R_1 (\text{high alumina cement}) = \frac{2.5 \text{ inches}}{K} = \frac{2.5}{6} = 0.42$$

$$Q = \frac{1100 \times 12}{0.42} = 31,400 \text{ Btu/hr}$$

$$Q_b (\text{With Insulation}) = \frac{(1300 - 200) 12}{R_1 + R_2}$$

$$R_1 = \frac{2 \text{ inches}}{6} = 0.333$$

$$R_2 (\text{ceramic fiber}) = \frac{0.5}{K} = \frac{0.5}{0.29} = 1.72$$

Note: Ceramic fiber layer assumed to have a mean temperature below 600°F.

$$Q_b = \frac{1100 \times 12}{0.333 + 1.72} = 6,400 \text{ Btu/hr}$$

$$\text{Reduction in heat loss} = 31,400 - 6,400 = 25,000 \text{ Btu/hr}$$

Equivalent to 79.6% savings in energy.

From previous example, net reduction in energy usage is:

$$31,400 \text{ Btu/hr} \times 0.796 = 25,000 \text{ Btu/hr}$$

At \$0.3 per therm, cost reduction

$$\frac{25,000 \times 0.3}{100,000 \text{ Btu/Therm}} = \$0.075/\text{hr}$$

Based on 20% utilization, 8 hours per day, 240 days per year, annual energy cost savings is = $0.075 \times 8 \times 240 \times 0.2 = \$28.80/\text{year}$.

SUMMARY (PROBABLE ENERGY SAVINGS)

The following table summarizes present and probable energy requirements for ladle heating as determined in sample calculations if all the improvements are carried out.

ITEM	BTU/HR SAVED	%SAVINGS	ANNUAL GAS THERMS	SAVINGS COST \$
Covers	320,000	58.0	1,233	370
Combustion System	138,000	60.0	533	160
Insulation	25,000	79.6	96	30
EQUIPMENT TOTAL	483,000	--	1,862	\$560

Actual overall energy saving between 50% and 60% is considered to be practical for the majority of ladle heating operations. Additional savings can be realized if ladle heater utilization is reduced to 15% of the typical 8 hour shift period.

ECONOMIC EVALUATION

ITEM

1. Provide insulated cover (material cost)	= \$ 500.00
2. Replace burner with 'High Efficiency' unit with gas controls	= 4,000.00
3. Add insulation to ladle lining 1/2" x 12 sq. ft. (material cost)	= 50.00
4. Labor to install cover	= 450.00
	<hr/>
	SUBTOTAL \$ 5,000.00
5. 10% Engineering cost	500.00
	<hr/>
	TOTAL \$ 5,500.00

$$\text{Payback period} = \frac{\text{Capital Investment}}{\text{Energy Savings}} = \text{years}$$

$$\text{Thus payback} = \frac{5,500}{560} = 9.8 \text{ years}$$

Note - installation of insulated lining is assumed to be carried out during normal reline schedule and labor cost is expensed. The above costs are "order of magnitude" only.

PART C
COKE FUEL MELTING - CUPOLA

GENERAL

Methods of melting to be analyzed in this section are:

Lined Cold Blast Cupola

Lined Cupola With 500°F Hot Blast

Water Cooled Cupola With 1,000°F Hot Blast

Divided Blast Cupola, Cold Blast

Lined Cupola, Cold Blast With 2-4% Oxygen Enrichment

COKE USAGE

The conventional cupola is a vertical shaft type furnace with refractory lining and equipped with a windbox and tuyeres for the admission of air. The sequential material charges, through the stack of the cupola, comprise alternate layers of metallics and coke with some fluxes added. The descending fuel replaces that burned from the original coke bed and maintains the height of this bed.

COKE BED CALCULATIONS

Example

Bed coke height above tuyeres is;

$10.5 \times \text{sq. root of blast pressure (onces)} + 6$

Therefore if windbox pressure = 16 onces

Bed coke height = $(10.5 \times 16) + 6 = 48"$

Thus the volume of bed coke required per melt campaign is obtainable by reference to Table 1. Consider above example and determine weight of coke required in initial bed as follows:

Read Table 1, for volume at 16 onz. pressure = 38.5 cu. ft., therefore at 30 lbs/cu. ft., weight of coke = 1155 lbs.

Additional coke may be required to be added to maintain bed height during initial melt period, to obtain full burning of the bed prior to the first charge of metal, also for starting the blast. Additional coke to fill the hearth up to tuyere level, must be made based on specific cupola design. Total energy required to operate the cupola, including bed coke and electric power, is to be calculated as shown on the work sheet as follows:

STANDARD CALCULATION FORMAT FOR CUPOLA ENERGY DATA

Standard 48" Lined, Cold-Blast Cupola.

Melt rate TPH. 9.0 x 2000 18,000 lbs/hr.

Metal to Coke ratio 10:1, Coke charged/hr 1,800 lbs.

CFM Air Req'd. 4,100 @ Blast Pressure 18 ONZ

Fan HP 50.0

Skip Loader 7.5

Dust Collector 55.0

Misc. Power 5.0

Equivalent BTU/HR $\frac{117.5 \times .746 \times 3412}{1.73} = 172,878$

Coke Charged/HR 1800 LBS/HR

Bed Coke x 1/8 225

Equivalent BTU/HR 2,025 x 12,500 = 25,312,500

TOTAL BTU/HR = 25,713,410

AVERAGE BTU/TON OF METAL CHARGED = 2,831,700

OPERATION OF SPECIAL CUPOLAS

Comparison of current cupola operation with alternate systems, hot blast type, divided blast or oxygen enriched blast, can be made by reference to the model energy chart graphs at specific melt rate requirements.

It is assumed that the cupola melt rate, in all cases, is based on conventional practice prior to improvements.

TABLE 1. BED COKE REQUIREMENTS

NORMAL WINDBOX PRESSURE (OZ)	BED COKE ABOVE TUYERES (INCHES)	MELT DIAMETER (INCHES)	ZONE AREA (SGINS)	VOLUME COKE (CU. FT.)
7	28-34	18	254	5.0
12	36-42	23	415	10.0
14	40-46	32	804	21.4
16	42-48	42	1,385	38.5
18	45-51	48	1,809	53.4
20	47-53	72	4,071	124.9

Assumption:

Density of Cupola Coke = 30 lbs/cu.ft.

TABLE 2. CUPOLA OPERATING CHARACTERISTICS

IRON TO COKE RATIO	COKE PER TON OF MELT LB	MELTING RATE TONS PER HOUR	METAL TEMPERATURE °F	APPROXIMATE THERMAL EFF., %
12 to 1	167	16.0	2,656	46.7
11 to 1	182	15.2	2,672	43.0
10 to 1	200	14.2	2,686	39.5
9 to 1	222	13.1	2,706	36.0
8 to 1	250	12.0	2,730	32.0
7 to 1	286	10.9	2,762	28.4
6 to 1	333	9.8	2,798	27.0

LINED CUPOLA - IRON MELTING

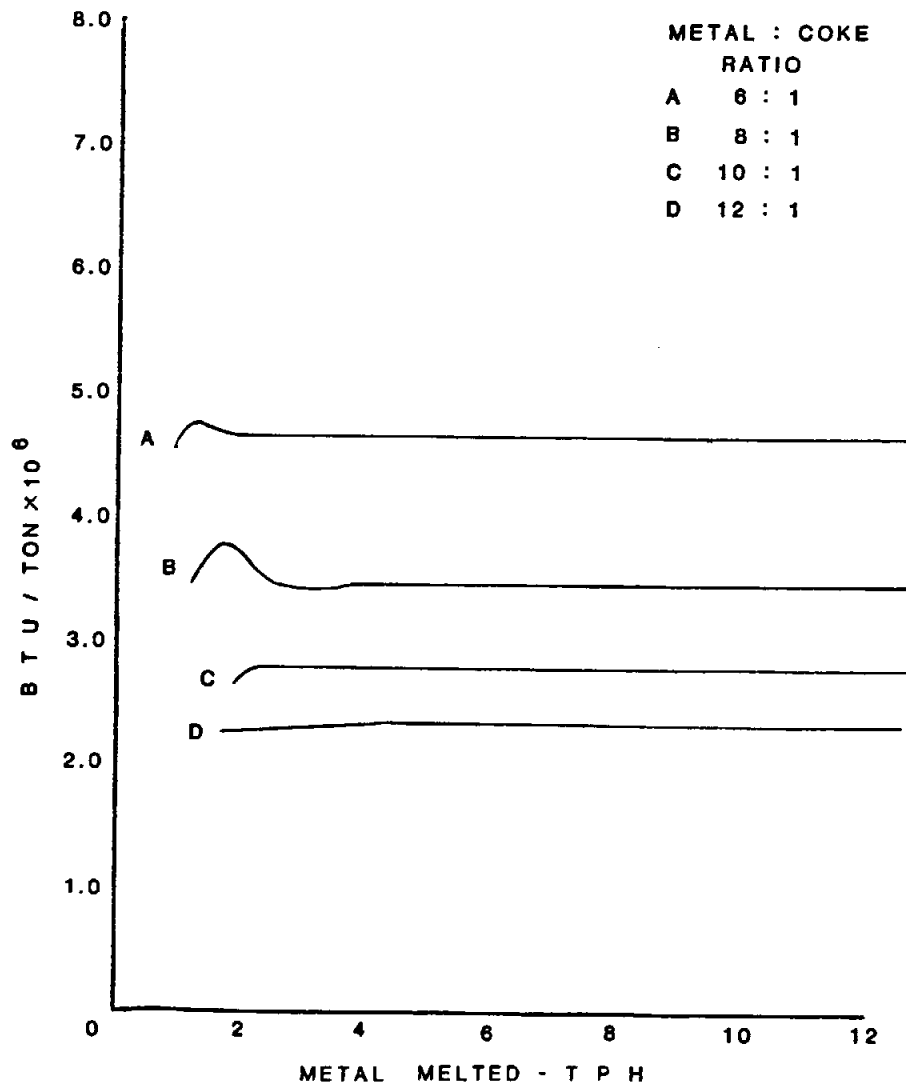


FIGURE 1

LINED CUPOLA 500°F HOT BLAST
MELTING GRAY IRON

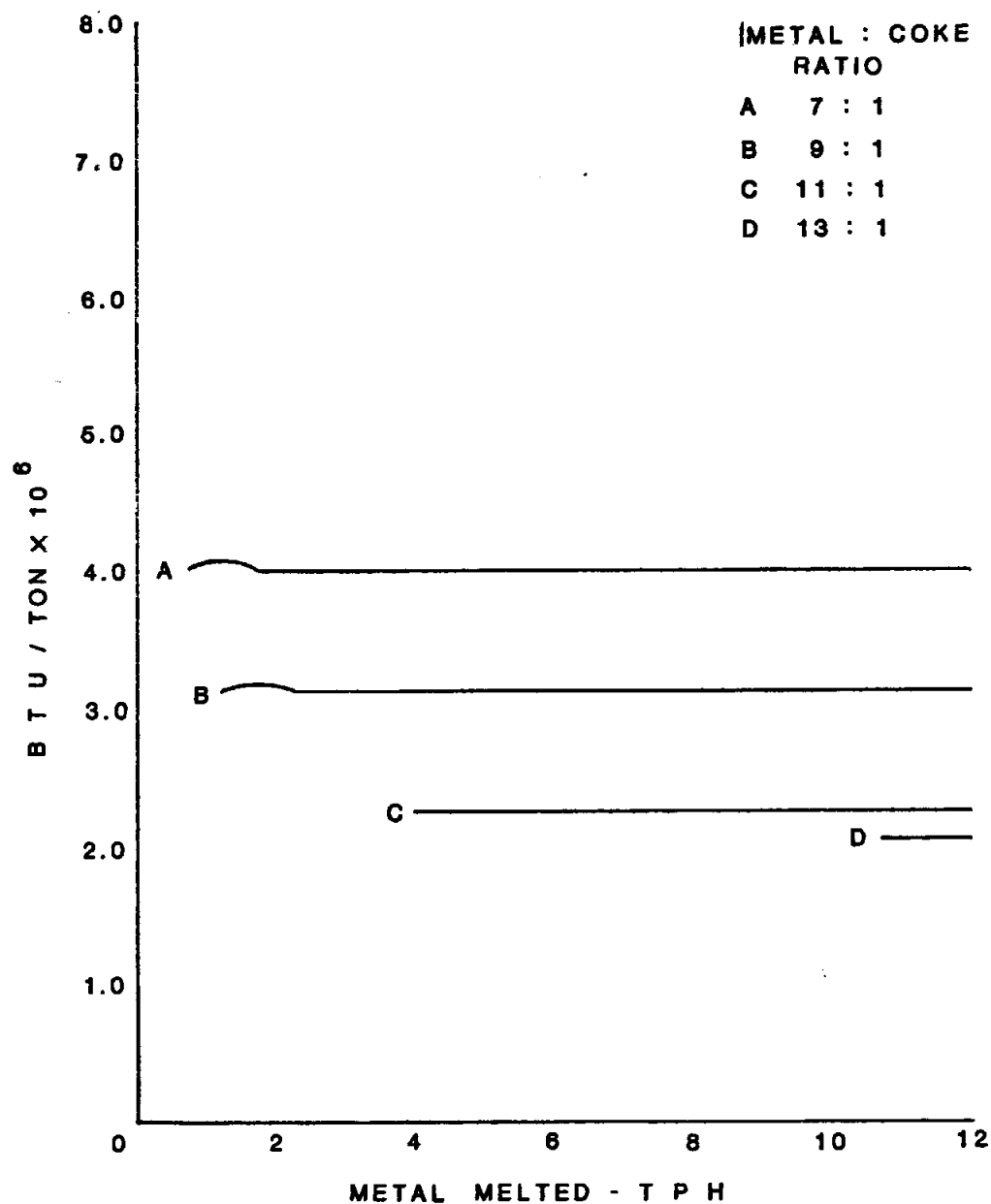


FIGURE 2

LININGLESS 1000 F° HOT BLAST CUPOLA MELTING GRAY IRON

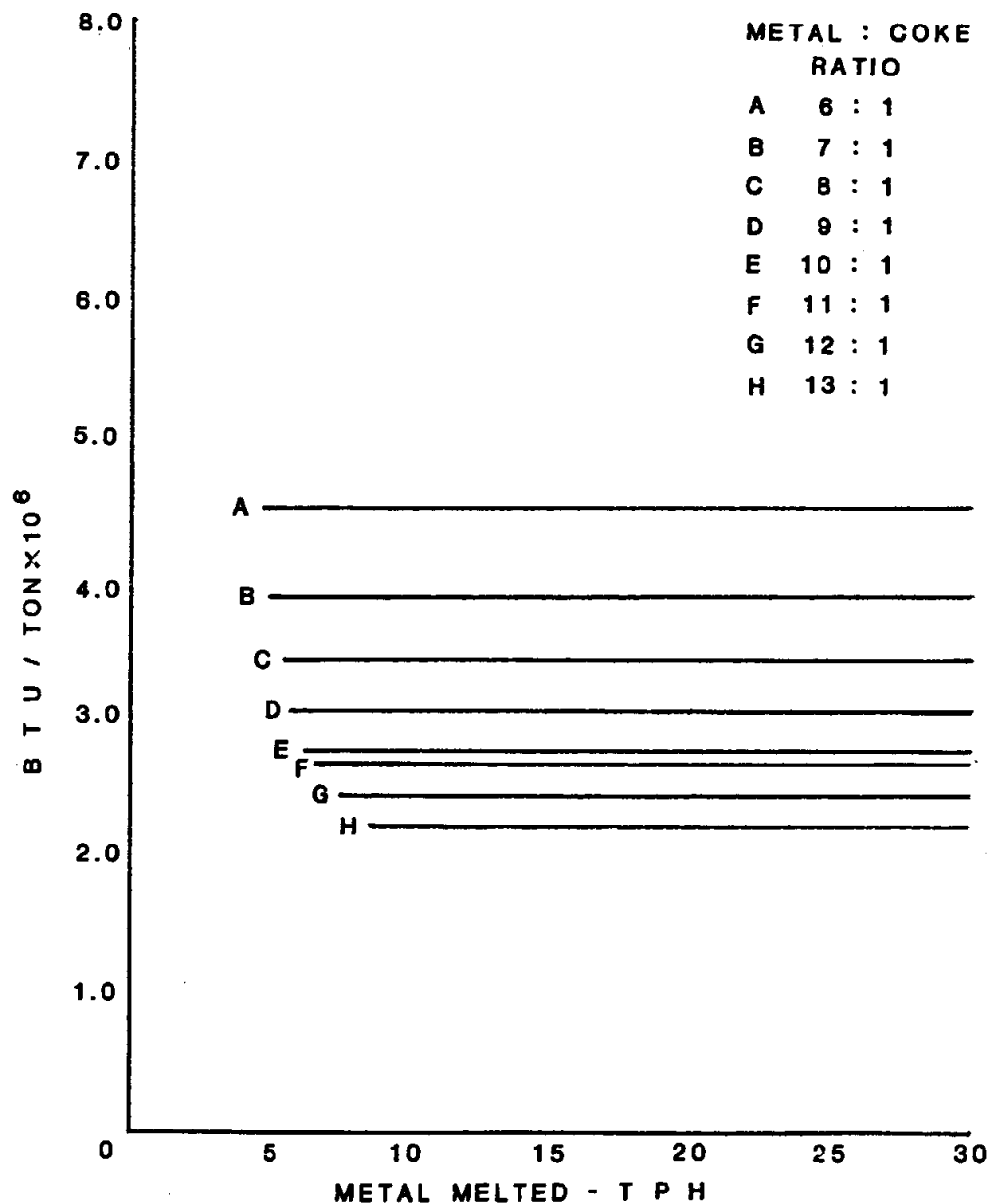


FIGURE 3

DIVIDED - BLAST CUPOLA

MELTING GRAY IRON

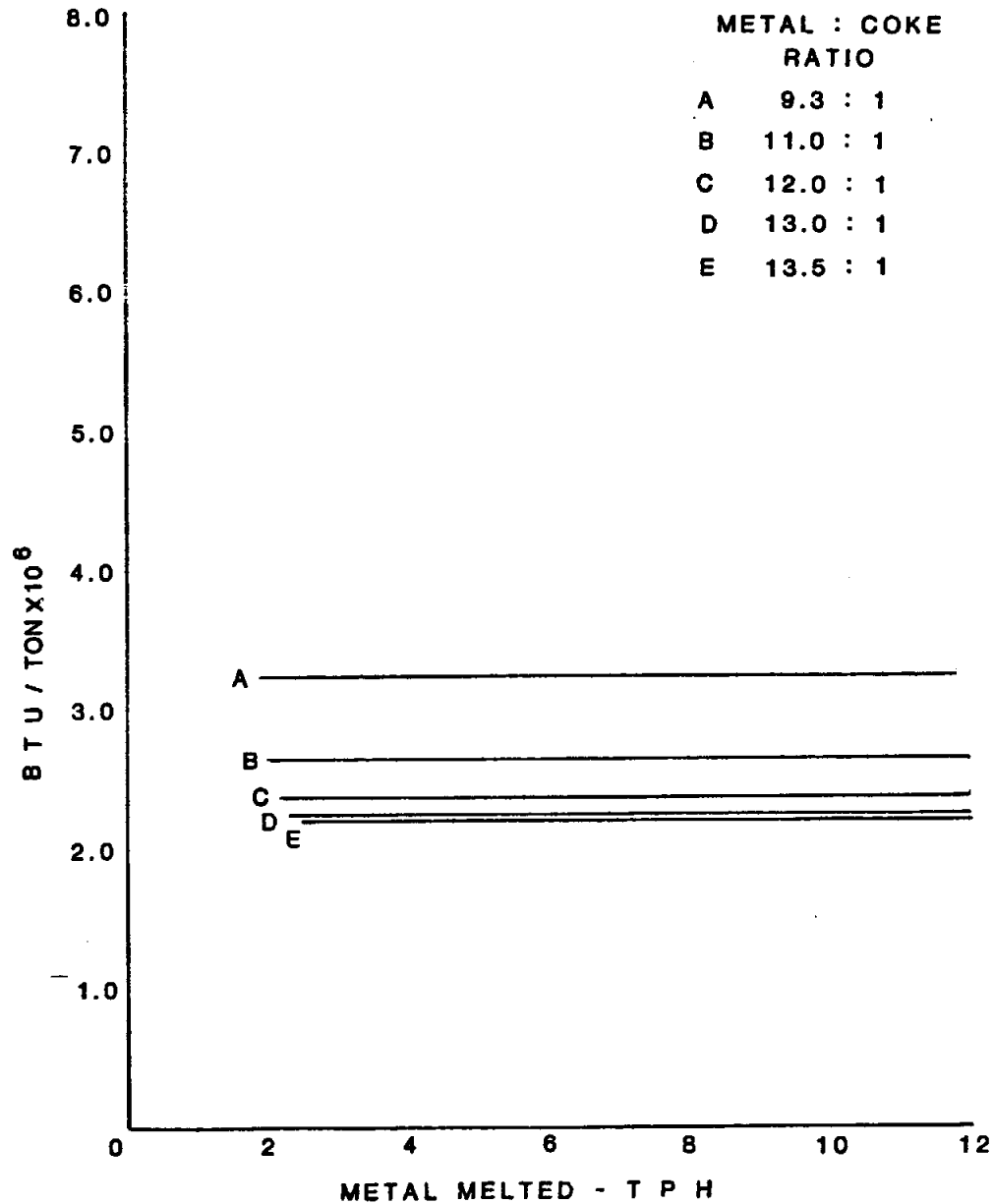


FIGURE 4

LINED COLD BLAST CUPOLA WITH OXYGEN ENRICHED BLAST

MELTING GRAY IRON

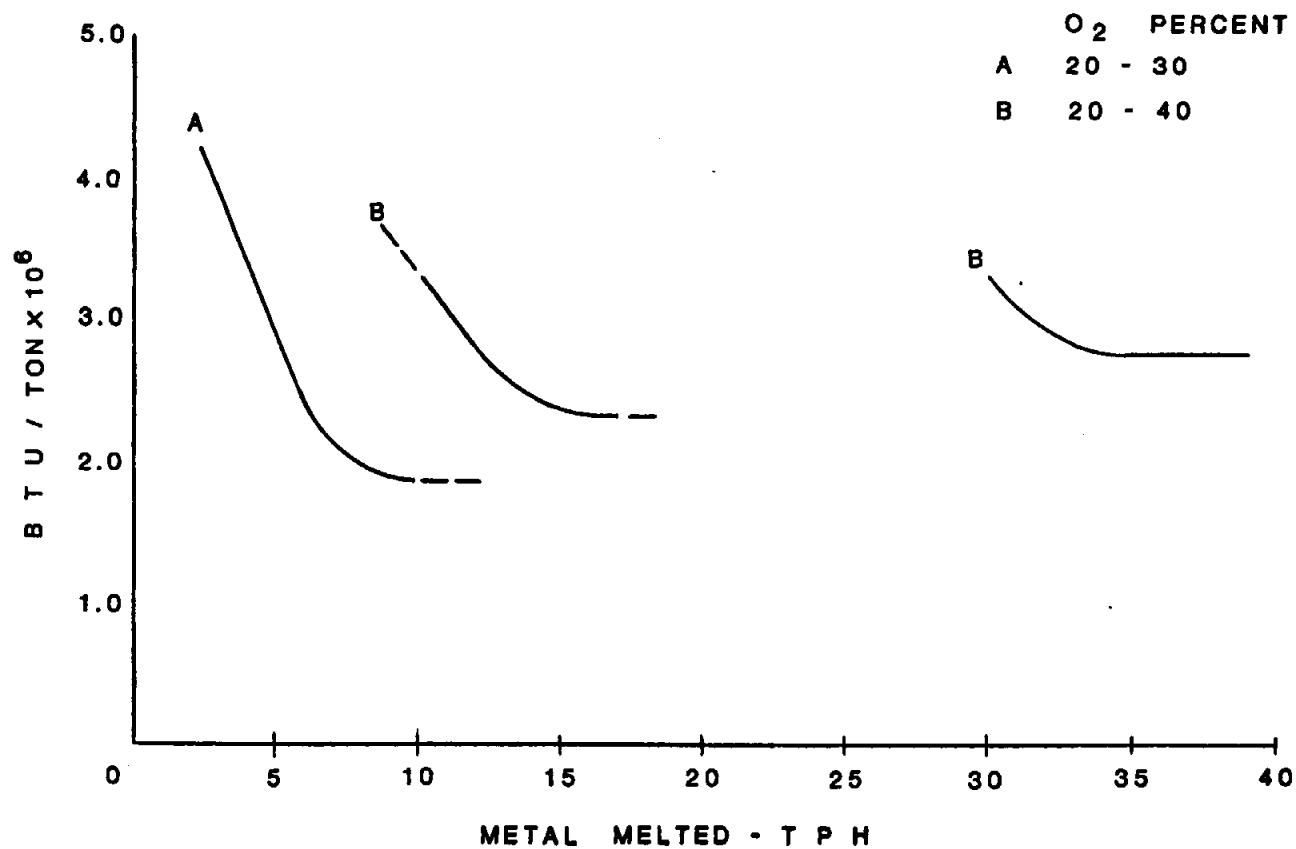


FIGURE 5

RELATIVE MELT RATE/HOUR FOR 1,000°F
HOT BLAST LINING LESS WATER-COOLED CUPOLA

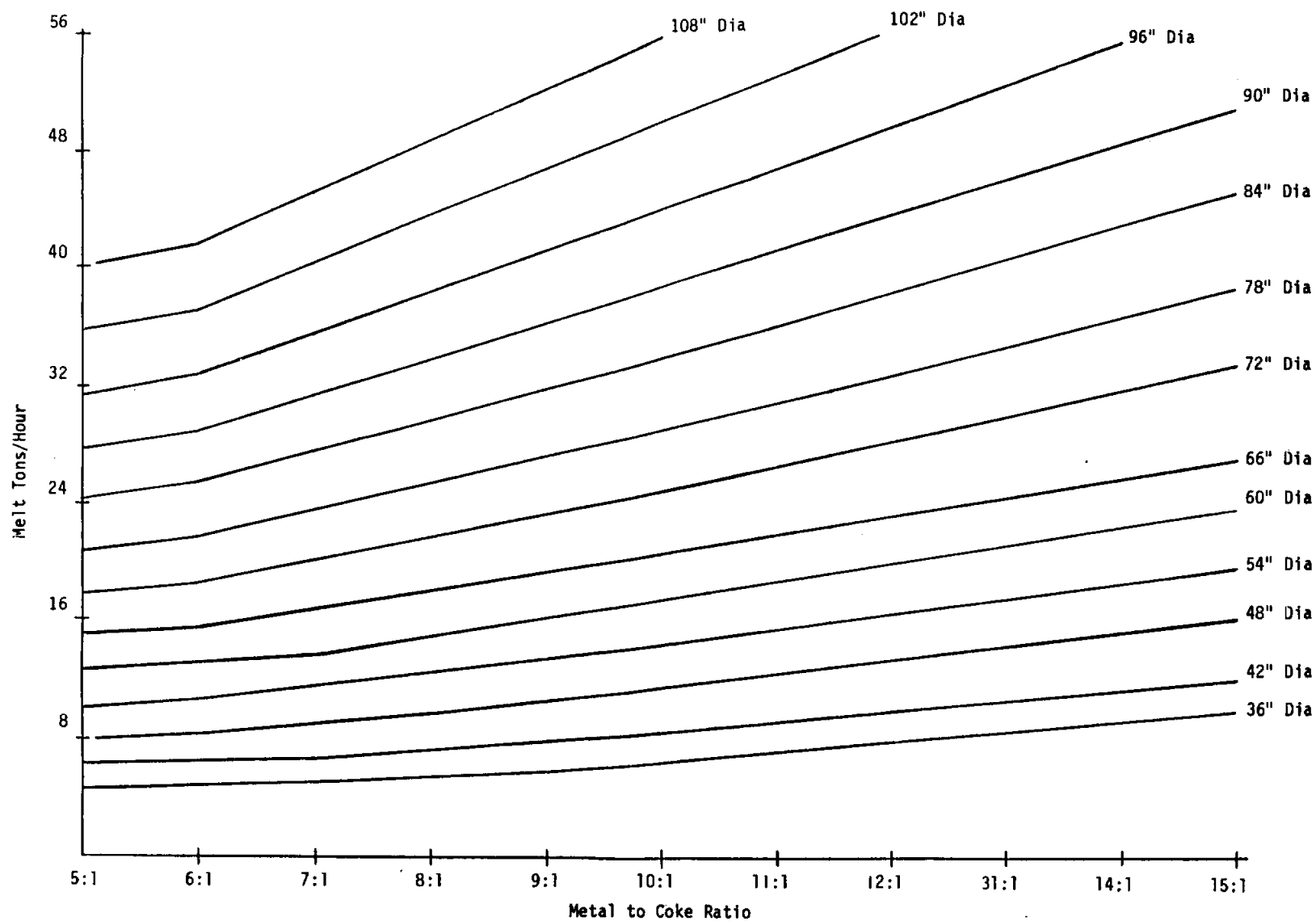


FIGURE 6

SPECIAL CUPOLA MELTING CONDITIONS

To obtain increased melting or higher temperature and more efficient coke usage, refinements to the standard cupola are available.

Blast conditioning, through utilization of recuperative hot blast, can be provided using the waste heat from the cupola exhaust. Approximately 60% of cupola effluent gas is utilized as fuel to combine with combustion air for the liberation of heat in the heat exchanges.

HOT BLAST SYSTEM

Model energy usage in BTU/ton of iron melted can be determined by reference to specific charts and by projecting a point on the graph, at known metal to coke ratio, from desired melt rate in tons per hour. (Figure 1).

Value determined from the graph can be compared to proposed operation under new conditions of operation, by calculation of actual energy usage difference for requirements, as per following example.

Example

In the previous example, the metal to coke ratio in a conventional cupola is 10:1. From Fig. 1, graph line C, the energy required to melt is 2.85×10^6 BTU/ton. (Includes melt coke, bed coke and electrical energy.)

From Figure 6, for conditions of 1,000°F hot blast, a similar size 48" diameter cupola is indicated to be capable of melting 14.2 tons/hr. at 13:1 metal to coke ratio.

Thus reading energy required for 1,000°F hot blast cupola at 13:1 metal to coke ratio, from Figure 3, is:

$$\text{Energy required} = 2.20 \times 10^6 \text{ BTU/ton}$$

$$\text{Reduction in energy/ton} = (2.85 - 2.20) 10^6 \text{ BTU/ton} = 650,000 \text{ BTU/ton}$$

$$\text{Which is equivalent to } \frac{0.65}{2.85} = 22.8\% \text{ improvement}$$

∴ Annual energy reduction based on 15,000 tons of metal melted

$$\text{per year} = \frac{650,000 \text{ Btu/ton melted}}{12,500 \text{ BTU/lb.}} = 52 \text{ lbs coke/ton}$$

$$\text{At } \$0.10 \text{ per lb, cost reduction} = 52 \times 15,000 \times 0.10 = \underline{\$78,000 \text{ per year}}$$

COKE TO METAL RATIO (TAP TEMPERATURES)

The range of sizes and operating recommendations for conventional cupolas has been developed over a long period of time resulting in fairly standard data (see TABLE 2). Ratio of metal weight to coke charged, excluding the bed coke, determines the melt rate and/or temperature of iron as it leaves the cupola. Higher tapping temperatures involve a penalty in coke usage and melt rate, with conventional designed cupolas.

Example

If metal is to be tapped from a cupola at 2,762°F, calculate the energy (coke) penalty compared to tap temperature of 2,686°F. From table 2, a cupola producing 10.9 tons per hour with iron to coke ratio of 7:1 for 2,762°F tap temperature, results in approximate thermal efficiency of 28.4% at 2,686°F.; the cupola would produce 14.2 tons/hour with iron to coke ratio of 10:1 and approximate thermal efficiency of 39.5%.

Thus at 7:1 ratio, coke usage = 286 lbs/ton melted

10:1 ratio coke usage = 200 lbs/ton melted

Reduction = $\overline{86}$ lbs/ton melted

∴ Penalty for 76°F super heat is equivalent to:

$$86 \times 12,500 \text{ BTU/lb} = 1.075 \times 10^6 \text{ BTU/ton melted}$$

At \$0.10 per lb for coke, the cost difference

$$= 86 \times 0.10 = \$8.60 \text{ per ton melted}$$

Annual energy reduction based on 15,000 tons per year of metal melted

$$= 1.075 \times 10^6 \times 15,000 = \underline{16,125 \times 10^6 \text{ BTU}}$$

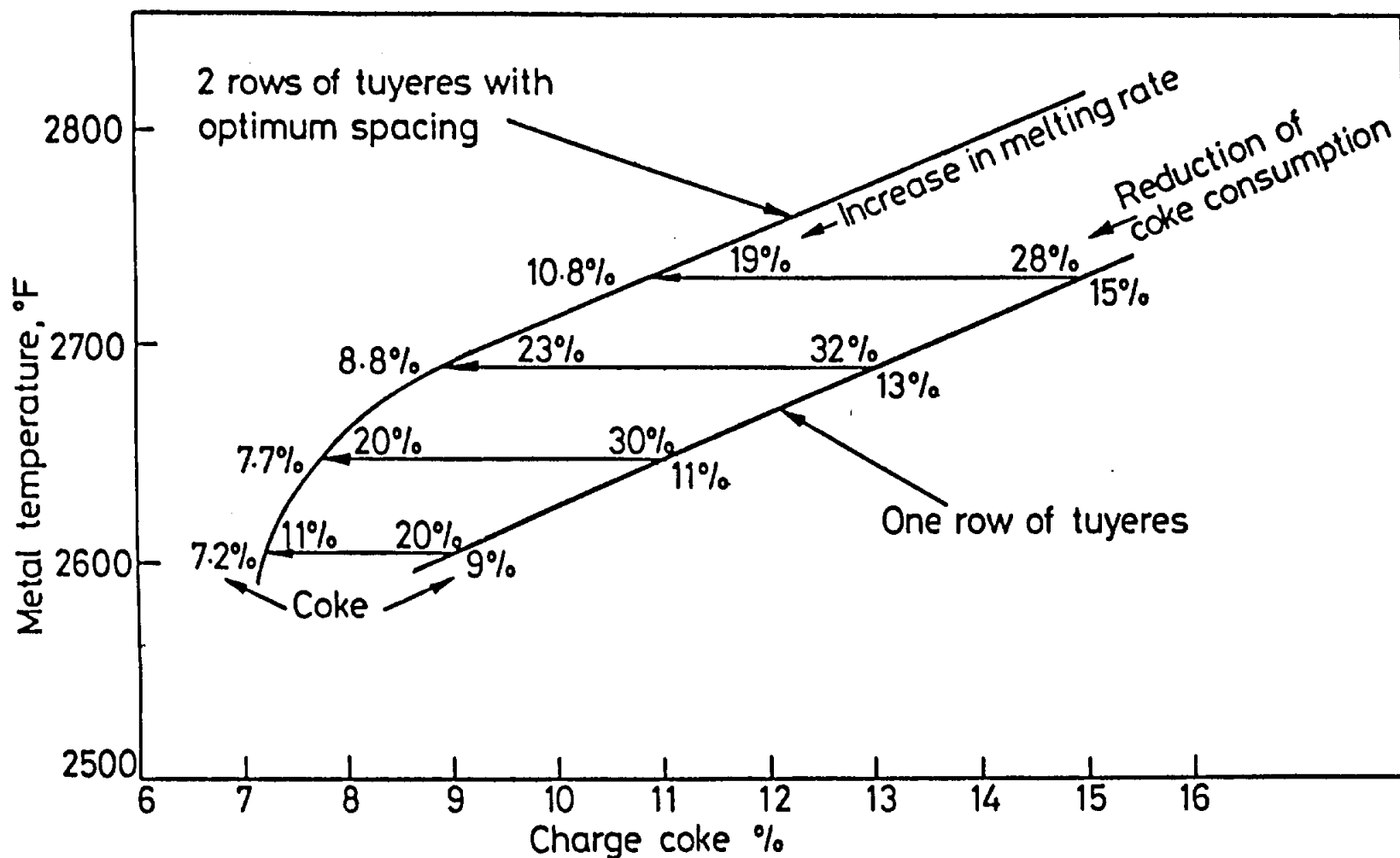
$$\text{Energy reduction} = \frac{86}{286} = 30.0\%$$

$$\text{Cost savings per year} = \$8.60 \times 15,000 = \underline{\$129,000}$$

$$\text{Thermal efficiency improvement} = 39.5 - 28.4 = 11.1\%$$

Note- In above example the coke bed height in each case is the same and does not effect the melting energy difference.

Tap temperature reduction may be impractical without other operational improvements such as insulation of launders, pouring ladles, etc. Control of production scheduling is required to minimize holding periods or delays prior to pour off; also, redesign of gating to enable lower casting pouring temperatures is another requirement.



Reduction of charge coke consumption and increase in melting rate by operating cupola with two rows of tuyeres with divided-blast supply (Blast rate 1600ft³/min)

FIGURE 7

Revised energy requirement; divided blast cupola, per ton
= $2.20 \times 10^6 - 577,500 = 1.62 \times 10^6$ BTU

By calculation, the new metal to coke ratio is equivalent to energy required at 15.8:1 metal to coke ratio or approximately 126 lbs of coke per ton of melt.

∴ Annual energy reduction based on 15,000 tons of melt required per year = $577,500 \times 15,000 = 8662.5 \times 10^6$ BTU

Percent energy reduction = $\frac{577,500}{2.20 \times 10^6} = 26.2\%$

Cost reduction for 15,000 tons per year melt requirement

= $15,000 \text{ tons} \times 46.2 \text{ lbs/ton} \times \$0.10/\text{lb} = \underline{\$69,000/\text{yr.}}$

OXYGEN ENRICHED BLAST SYSTEM

A minimum production rate of 15 tons/day and 3 days per week is generally needed to justify the use of oxygen to gain production increase. Also no major reduction in coke usage occurs above 10 tons per hour melt rate with 2 - 3% O_2 enrichment. Savings at lower production rates are obtained as follows:

Example

Increased melting rate and/or tap temperature can be obtained by oxygen enrichment of 2 - 3%.

The total energy required can be read from graph 'A' Fig. 5 for production under 10 tons/hour.

Thus energy at 9 tons/hour metal melted = 1.85×10^6 BTU/ton.

Energy reduction compared to say a divided blast cupola (ref. Fig. 4) with metal to coke ratio of 13.5:1 (graph "E")

$2.20 \times 10^6 - 1.85 \times 10^6 = 350,000$ BTU/ton

Percent savings = $\frac{350,000}{2.20 \times 10^6} = 16\%$

Cost reduction based on reduction of coke = $\frac{350,000}{12,500} \text{ Btu/lb}$

= 28 lbs/ton melted at \$0.10 per lb, the annual savings in coke

energy for 15,000 tons melted = $15,000 \times 28 \times 0.10 = \underline{\$42,000/\text{yr.}}$

OVERALL ENERGY SAVINGS

The following table summarizes the possible cost and energy savings by improvements to the cupola operation.

ITEM	BTU/TON SAVED	ENERGY % IMPROVEMENT	ANNUAL COKE THERMS	SAVINGS COST \$
Tap Temp. Reduction	1,075,000	30.0%	161,250	\$ 129,000
Hot Blast System	650,000	22.8%	97,500	78,000
Divided Blast System	577,000	26.2%	86,625	69,000
Oxygen Enrichment (Not Applicable)		-	-	-
TOTAL	2,302,000		345,375	\$ 276,000

$$\text{Percent energy use reduction} = \frac{2,302,000}{2,857,050} = 80.5\%$$

Original thermal efficiency (approx.) 28.4

Improved thermal efficiency

$$= \frac{\text{Heat in iron (approx. 405 BTU/lb.)} \times 100}{\text{Gross Energy Input}} = \frac{810,000 \times 100}{1.62 \times 10^6} = 50.0\%$$

ECONOMIC EVALUATION

The order of magnitude cost, to implement all improvements for the sample cupola considered, is used to emphasize the viability of large capital expenditures for energy conservation measures. The payback is further improved, if full tax credits are accounted for and adjustments made for impact of future energy cost.

Example

$$\text{Payback period} = \frac{\text{Capital Investment}}{\text{Energy Cost Savings/year}}$$

$$\therefore \text{Payback} = \frac{\$1,000,000}{276,000} = \underline{3.6 \text{ years}}$$

COKE VS. ELECTRIC

COMPARATIVE ANALYSIS

To determine the best method, involves consideration of a complex interrelationship of specific foundry needs, relative to furnace operation. Energy for melting is only one aspect and not necessarily the primary factor, however, this analysis deals with differences in costs of melting due to energy only.

Based on calculated cost of energy developed elsewhere in this study, the cost of potential heat by alternate methods is summarized as follows:

Item	Foundry Coke	Electricity (Ave.)
Cost of Energy	\$167.50/net ton	\$ 0.0400/KWA
Potential Heat		
Content	12500 Btu/lb.	3415 Btu/KWH
Cost per million		
Btu	\$6.70	\$ 11.70

Energy for pre-heating, melting and superheating 1 ton of cast iron to 2,700°F.

$$552 \text{ Btu/lb} \times 2000 = 1,100,000 \text{ Btu/ton}$$

Percent of energy requirement for each phase of the melting cycle is as follows:

Btu/lb.

Pre-heat to melt temp.	$552 \text{ Btu/lb} \times 65\% = 358.8$
Melt to liquid state	$552 \text{ Btu/lb} \times 22\% = 121.4$
Super heat to 2,700°F	$552 \text{ Btu/lb} \times 3\% = 71.8\%$

For melting efficiencies of different types of equipment used for melting cast iron (see Figure 1.).

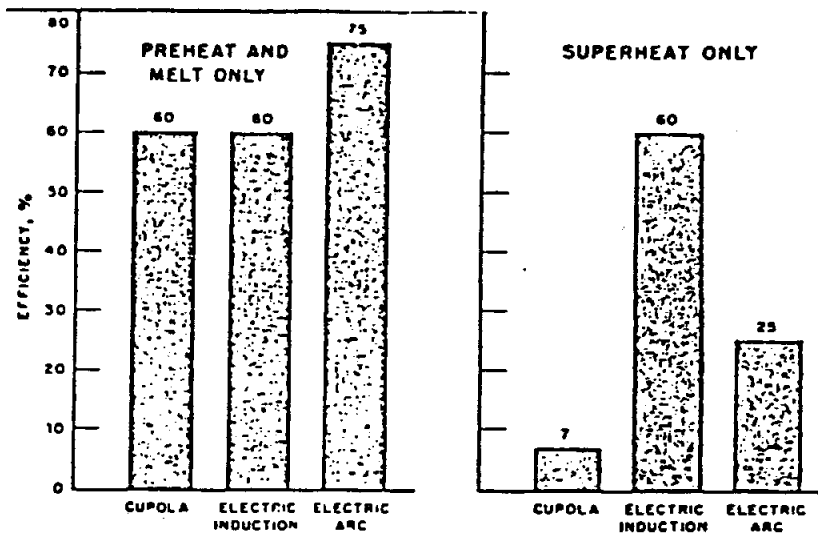


FIGURE 1. MELTING EFFICIENCIES

The following TABLE compares the three practical melting methods with respect to energy economics.

ITEM	CUPOLA	ELECT. INDUCTION	ELECT. ARC.
Cost to preheat	\$ 8.01	\$ 13.99	\$ 11.19
Cost to melt	2.71	4.73	3.79
Cost to superheat	13.74	2.80	6.72
TOTAL	\$ 24.46	\$ 21.52	\$ 21.70
BTU's required x 10 ⁶	3.65	1.84	1.85

Example

Cost to pre-heat one ton of metal by cupola to melt temperature;

$$\text{Btu required} = \frac{35.8 \text{ Btu/lb} \times 2000 \text{ lbs}}{60\% \text{ Efficiency}} = \frac{0.72 \times 10^6}{0.60} = 1.196 \times 10^6$$

$$\text{Cost of energy @ \$6.70 /million Btu} = 1.196 \times 6.70 = \$8.01$$

On the basis of this analysis, the electric induction furnace is more energy efficient. However, the analysis can be applied to any combination of melting methods to obtain the most energy cost effective results (See Figure 2).

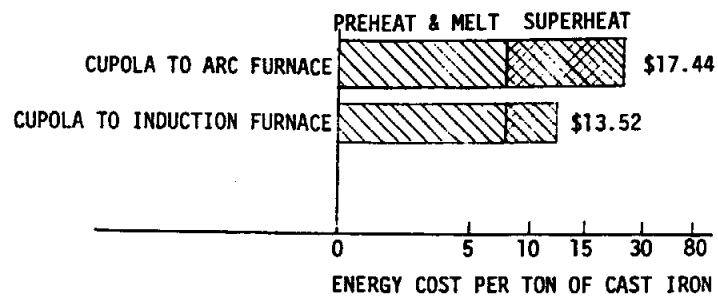


FIGURE 2

Subject to the practical feasibility of these combinations and not accounting for other capital or operating costs, the cupola to induction furnace approach at \$13.52 per ton melted is the least cost. Btu's required by this method based on previous calculations are:

Cupola	1.60×10^6
Induction	0.24×10^6
TOTAL	1.84×10^6 Btu/ton

PART D

GAS-FIRED CHARGE PREHEATING

GENERAL

Furnace charge preheating, up to 1,000°F for iron, results in energy and cost reductions of up to 25%.

This section deals with charge preheating by;

- Gas-fired burner units.
- Oxygen assisted burners.

Diagrams and tables indicate typical data and performance for equipment commercially available. Similar information should be reviewed from alternate sources prior to actual energy audit work being carried out.

Example

Required, scrap preheat temperature of 1,000°F for batches of one ton size to be charged to an electric melting unit, operating 8 hours per day, 240 days per year at annual rate of say 3,000 tons of gray iron.

Increased melt production percentage is obtained by reference to Figure 1, reading for 'iron' at 1,000°F scrap temperature.

@ 1,000°F, resulting increase = 30%

Equivalent Energy Requirements:

Natural Gas-Fired Unit:

@ 1,000°F = 600 cu. ft/ton = 600,000 Btu (from Table 1)

Thus: Cost @ \$0.3/Therm x 6 Therms = \$1.80/ton

Electrical Energy Usage Reduction

@ 1,000°F = 117 kW/ton (from Table 1)

Thus: Cost @ \$0.042 per kW = \$4.91/ton

Net cost savings = (4.91 - 1.80) = \$3.11 per ton

Annual cost reduction = 3,000 x 3.11 = \$9,330

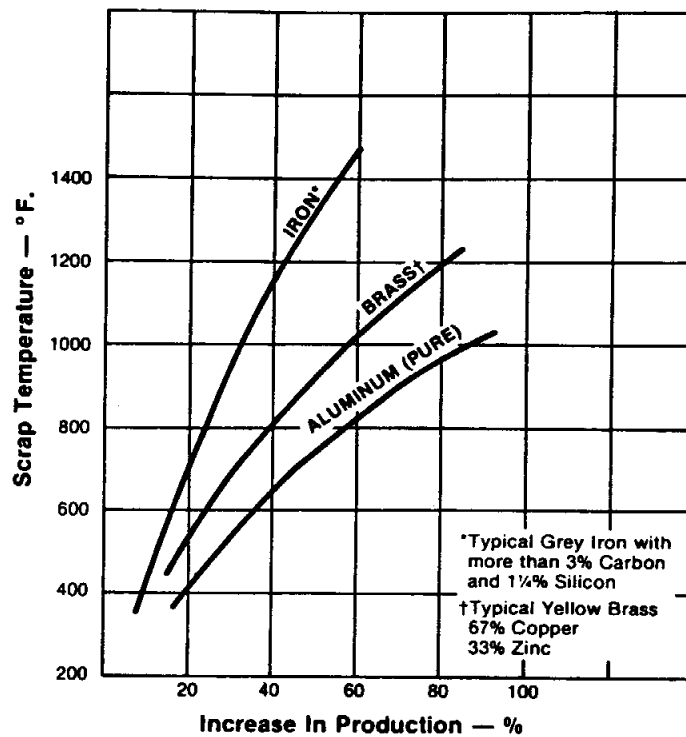


FIGURE 1. INCREASED MELT PRODUCTION

TABLE 1

Furnace Charge Preheating Energy Comparison for Arc and Induction Melting of Iron, Aluminum and Brass

Efficiency Basis: Induction Furnace @ 70%/Fuel (Gas, Propane, Oil @ 47% to 93%, depending on Temperature).

Preheat Temp. ° F.	KW Usage per Ton Cold Melt			Venetta Usage per Ton/CF Natural Gas @ 1000 BTU/Cu. Ft.			Venetta Usage per Ton/Gal. Propane @ 91,735 BTU/Gal.			Venetta Usage per Ton/Gal. #1 or #2 Fuel Oil @ 138,000 BTU/Gal.		
	Iron	Alum.	Brass	Iron	Alum.	Brass	Iron	Alum.	Brass	Iron	Alum.	Brass
500	59	101	44	150	256	105	1.64	2.8	1.14	1.1	1.9	.8
600	70	121	53	216	365	151	2.4	4.0	1.65	1.6	2.6	1.1
700	82	141	62	276	469	193	3.0	5.0	2.1	2.0	3.4	1.4
800	94	161	70	372	640	261	4.1	7.0	2.8	2.7	4.6	1.9
900	106	181	79	480	808	332	5.2	8.8	3.6	3.5	5.9	2.4
1000	117	201	89	600	1012	417	6.5	11.0	4.5	4.3	7.3	3.0
1100	129			792			8.6			5.7		
1200	141			1008			11.0			7.3		
1300	152			1320			14.4			9.6		
1400	164			1680			18.3			12.2		

OXYGEN-FUEL ASSISTED MELTING

Oxy-fuel assisted melting involves supplying additional heat energy during melt down by introducing oxygen as a fuel to supplement or replace the electrical power input to the furnace. Oxy-fuel assisted melting practice has been applied successfully to most nonferrous and ferrous metals with the exception of brass which exhibits high zinc loss. Suitable stoichiometric firing rates are chosen for each metal to minimize oxidation.

Note: Wellman Alloys Limited of England used oxy-fuel (propane) burner - melting rate increased by 80% - energy savings in excess of 15%.

Example

Data based on various induction furnaces incorporating oxy-fuel indicates average of 26% improvement in power input, reference Table 2.

TABLE 2. OXY-FUEL ASSISTED MELTING IN INDUCTION FURNACES

Data Obtained From Various Induction Furnaces Incorporating Oxy-Fuel						Melt Down Time Tap to Tap, Min.			Furnace Electrical Power Input, kw/ton			Melting Rates, ton/hr			
Case No.	Furnace Capacity Ton (kg)	Furnace Rating kw	Material Melted	Fuel	Stu/ton x 10 ⁴ (kwh/ton)	Normal	Assisted	Improvement, %	Normal	Assisted	Improvement, %	Normal	Assisted	Improvement, %	
1	.3 (305)	200	Ductile Iron	Propane	.775 (227)	73	51	30	897	628	30	.246	.354	44	
2	.5 (509)	150	Ni Cr Alloy	Propane	.60 (176)	150	95	36	1040	720	31	.20	.316	58	
3	1.0 (1018)	300	Carbon Steel	Propane	.3175 (93)	150	105	30	815	680	17	.42	.60	43	
4*	1.0 (1018)	300	Ni Cr Alloy	Propane	.825 (183)	184	97	47	863	500	42	.325	.612	88	
5	1.0 (1018)	600	Ni Cr Alloy	Butane	.592 (173)	90	60	33	733	630	14	.68	.89	31	
6	2.0 (2036)	800	Alloy Steel	Nat. Gas	.503 (147)	175	135	23	778	610	22	.67	1.0	49	
7	3.0 (3054)	800	Gray Iron	Propane	.730 (214)	190	125	34	770	525	32	.632	.976	54	
8	3.0 (3054)	800	Gray Iron	Propane	.297 (87)	95	77	36	680	471	19	.840	1.364	62	
*Case 4: Figures and Results are for Flat-Bathronly, Courtesy Wellman Alloys Ltd., Amblecote, Stourbridge, West Midlands, England.						Average Improvement			34.5 Average Improvement			26 Average Improvement			48.5

Extracted from Foundry M & T MPS - March 1978
by J. Allread / Grede Foundries, Milwaukee

Example

Alloy steel melted in 2.0 ton capacity, 600 kW rating furnace indicated 32% power reduction:

$$\text{Power improvement} = \frac{778 - 610}{778} = 22.0\%$$

$$\begin{aligned}\text{Reduction in electricity} &= 168 \text{ kWh/ton} \\ &= 573,200 \text{ Btu/ton}\end{aligned}$$

$$\begin{aligned}\text{Electric cost reduction @ } \$0.042/\text{kW} &= 168 \times 0.042 \\ &= \underline{\$7.05/\text{ton}}\end{aligned}$$

$$\text{Added Natural Gas usage} = 0.503 \times 10^6 \text{ Btu/ton}$$

$$\text{Therms} = \frac{0.503 \times 10^6}{100,000 \text{ Btu/Therms}}$$

$$\text{Natural Gas cost addition @ } \$0.3/\text{Therms} = \underline{\$1.51/\text{ton}}$$

$$\begin{aligned}\text{Annual cost reduction based on 3,000 tons melted per year} \\ = (7.05 - 1.51) 3,000 &= \underline{\$16,660}.\end{aligned}$$

SUMMARY

ITEM	BTU/TON SAVED	THERMAL EFFICIENCY	ANNUAL SAVINGS	
			THERMS	COST
CHARGE PREHEATER	(200,000)	-	(6,000)	\$ 9,330
OXY-FUEL ASSIST.	70,000	-	2,100	16,600
TOTAL	(130,000)	-	(3,900)	\$ 25,930

ECONOMIC EVALUATION

1. Charge preheater 1 ton capacity to operate at 1,000°F.	\$55,000
2. Oxy-fuel burner system.	23,000
3. Installation at 25%	20,000
	Subtotal
	\$98,000
4. 10% Engineering	9,800
	Total
	\$107,800

$$\text{Payback period} = \frac{\text{Capital Expenditure}}{\text{Cost Reduction/Yr.}} = \text{Years}$$

$$\text{Payback} = \frac{107,800}{25,930} = 4.15 \text{ Years}$$

PART E

ENERGY SAVING CHECK LIST

Many energy saving opportunities exist in all foundries that can be instituted immediately without requiring large capital equipment investments. The checklist that follows presents these no cost/low cost energy saving ideas together with suggestion modifications and changes that will require medium to major capital investments:

INFILTRATION

Infiltration--Infiltration of cold air into the plant through cracks, openings, gaps around doors and windows, etc., increases the building's heat load and may be responsible for 20 to 25 percent of the yearly space-heating energy consumption. This waste can be eliminated, and an additional saving in heating realized, by taking the following steps:

- ___ 1. Replace broken or cracked window panes.
- ___ 2. Caulk cracks around window and door frames.
- ___ 3. Weatherstrip windows and doors.
- ___ 4. Close windows while the building is being heated.
- ___ 5. Check sealing gaskets and latches for all operable windows to see that they are working properly.
- ___ 6. Close all rolling-type doors when they are not being used.
- ___ 7. Eliminate unnecessary windows and skylights.

Heating, Ventilating, and Air-Conditioning (HVAC) Systems--HVAC systems have a significant impact on the plant's total energy consumption. These changes in operational routine can cut HVAC energy use 5 to 15 percent:

- ___ 1. Establish minimum temperature levels for the heating season and maximum levels for the cooling season. Establishing these levels requires consideration of occupied and unoccupied periods.
- ___ 2. Repair or replace all damaged or defective thermostats or control equipment; calibrate as necessary.
- ___ 3. Mount thermostats on inside walls and columns only.
- ___ 4. Lock all thermostats to prevent unauthorized personnel from tampering with them.
- ___ 5. Eliminate the use of mechanical cooling when the plant is unoccupied. Turn off heat or maintain a 50 F minimum in unoccupied areas.
- ___ 6. Inspect all outside air dampers to ensure that they establish an air-tight fit when closed.
- ___ 7. Establish startup and shutoff times for HVAC systems.
- ___ 8. Shut off or adjust HVAC systems during weekends and holidays.
- ___ 9. Minimize outdoor air intake.

APPLIES DOES NOT APPLY		COMMENTS

	APPLIES	DOES NOT APPLY	COMMENTS
<p>Makeup-Air Units--Whenever air must be heated, inefficiencies are probable. The following modifications to makeup-air units can help conserve energy:</p> <ol style="list-style-type: none"> 1. Adjust burners for proper flame patterns. 2. Clean burner nozzles periodically to remove mineral deposits and corrosion buildup. 3. Observe the fire when the unit shuts down. A fire that does not cut off immediately could indicate a faulty control valve. Repair or replace the control valve as necessary. 4. Keep all heat-exchanger surfaces clean. 5. Inspect casings for air leaks. Seal them as necessary. 6. Clean or replace air filters regularly. 7. Keep fan blades clean. 8. Inspect and lubricate motor bearing regularly. 9. Inspect fan inlets and discharge screens to keep them free of dirt and debris at all times. <p>Insulation--Transmission heat losses and gains through walls, glass, roof, floor, etc., can be controlled with adequate insulation. The savings depend on the loss reductions achieved. A 5 to 10 percent saving is possible.</p> <p>Lighting--Lighting represents a major portion of electrical energy use. A reasonable effort should be made to use only the amount of lighting necessary for safety and efficiency. Taking the following steps could lower plant electrical energy consumption approximately 5 to 15 percent:</p> <ol style="list-style-type: none"> 1. Use daylight for illumination when possible. Turn off lights when sufficient daylight is available. 2. Turn off lights at night and in unoccupied areas during the day. 3. Install simple timers on light switches throughout the plant, including in offices. 4. Keep lighting equipment clean and in good working order. 5. Replace burned out or darkened lamps and clean all fixtures. 6. Increase the light-reflective quality of walls and ceilings with light colors. Such improvements may permit additional lighting reductions. <p>Boilers--In any boiler operation, the main source of energy waste is inefficient combustion. A 10 to 25 percent energy saving is possible by regularly following these simple checks and guidelines:</p> <ol style="list-style-type: none"> 1. Inspect boilers for scale deposits. 2. Keep all heat-transfer surfaces as clean as possible to reduce temperature differences. 3. Follow the boiler manufacturer's recommendations. 4. Follow the feedwater treatment and blowdown procedures recommended by the supplier. This measure will save fuel by minimizing scale formation. 5. Inspect door seals and other seal gaskets. Leaking gaskets waste fuel; doors may be deformed. 6. Check boiler stack temperature. If it is too high (more than 150 to 200 deg F above steam temperature), clean the tubes and adjust the burner. 			

	APPLIES	DOES NOT APPLY	COMMENTS
<p>__7. Adjust the burner so that the stacks are free of haze.</p> <p>__8. Collect and analyze flue gas samples regularly to determine if combustion is efficient.</p> <p>__9. Minimize the amount of excess air supplied for combustion.</p> <p>__10. Operate only one boiler unless it cannot supply the load.</p> <p>__11. Prevent short-cycle firing.</p> <p>Steam Lines and Traps--Whether small or large, the leaks in steam piping, fittings, valves, and traps add up and can waste large amounts of energy. A detailed survey of all such piping should be made weekly or monthly and the following steps should be taken:</p> <p>__1. Repair or replace defective or missing insulation.</p> <p>__2. Inspect steam traps and replace those that are worn, inoperative, or improperly sized.</p> <p>__3. Inspect pressure-reducing and regulating valves and their related equipment. Adjust, repair, or replace as necessary.</p> <p>__4. Check pressure gauges and thermometers for recording accuracy.</p> <p>Fans, Pumps, and Motors--Proper maintenance of fans, pumps, and motors can significantly improve their operational efficiency. The following steps can save energy at almost no cost:</p> <p>Fans:</p> <p>__1. Clean the blades.</p> <p>__2. Inspect and lubricate bearings regularly.</p> <p>__3. Inspect belts for proper tension.</p> <p>__4. Keep inlet and discharge screens free of dirt and debris.</p> <p>Pumps:</p> <p>__1. Check packings for wear. Bad packings waste water and erode the shaft.</p> <p>__2. Inspect bearings and belts regularly.</p> <p>Motors:</p> <p>__1. Keep motors clean.</p> <p>__2. Prevent overvoltage and undervoltage.</p> <p>__3. Eliminate excessive vibration.</p> <p>__4. Correct loose connections, bad contacts, belts, pulleys, bearings, etc.</p> <p>__5. Check for overheating and provide adequate ventilation.</p> <p>__6. Prevent imbalance in power phase sources. This condition can cause inefficient motor operation.</p> <p>Domestic Hot and Cold Water--Following these guidelines can maximize the efficiency of domestic water use:</p> <p>__1. Inspect the water supply system and repair leaks, especially faucet leaks.</p> <p>__2. Inspect insulation on storage tanks and piping. Repair as needed.</p> <p>__3. Turn off the pump when the building is unoccupied, if hot water is distributed by forced circulation.</p> <p>__4. Inspect and test hot-water controls. Regulate, repair, or replace as necessary.</p> <p>__5. Disconnect all refrigerated water fountains, if acceptable to building occupants.</p>			

Compressed Air Systems

- 1. Install either solenoid valves or remote operated valves on assembly line air mains to eliminate normal or accidental air leaks during non-operating hours.
- 2. Avoid utilizing expensive city water for a once through compressor cooling system. Instead, investigate recycling cooling water through a cooling tower.
- 3. Investigate utilizing waste air compressor aftercooler cooling water (95-115°F.) as boiler make up. This both saves the energy that would be required to heat city water from 55° to 95° and reduces the waste water discharged to city sewers with a resultant sewer charge reduction. As a rule of thumb, this will result in a 2 gallon fuel oil saving per 1000 gallons of make up water.
- 4. Install solenoid valves on all machine air supply lines to limit air use to actual machine operating periods.
- 5. If large quantities of low pressure compressed air are required, consider installing a separate low pressure compressor rather than reducing from the main plant supply.
- 6. Be sure the compressed air intake is in a cool location. Every 5°F. drop in intake air temperature results in a 1% increase in compressed air volume for the same compressor horsepower requirements.
- 7. Extra air receivers at points of high periodic air demand may permit operation without extra air compressor capacity.
- 8. Keep compressor valves in good condition for maximum efficiency (worn valves can easily reduce compressor efficiency 50%). Many compressor manufacturers recommend removal and inspection every 6 months.
- 9. Match compressor pressure to actual system requirements. Operating a compressed air system at higher than required pressure results in higher compressor maintenance and reduced efficiency, as well as increased operating costs. Most air tools are designed to operate with 90 PSI at the tool. Higher pressures result in increased maintenance and shorter tool life expectancy. Typically, a 10% increase in pressure will reduce tool life about 14%.
- 10. Size air hoses for minimal pressure drop to air tools. For instance, a tool designed to operate on 90 PSI will operate on 80 PSI, but at a 15% reduction in production.
- 11. Consider the installation of double acting water cooled piston compressors rather than rotary screw compressors if the compressor will be operating at partial load much of the time. A double acting water cooled piston compressor requires as little as 5-7% of full load horsepower when unloaded, while a rotary screw compressor can require as much as 60-75% of full load horsepower when unloaded.

APPLIES
DOES NOT APPLY

COMMENTS

	APPLIES	DOES NOT APPLY	COMMENTS
<p>12. Locate and repair all piping leaks. Typically, many manufacturing plants lose about 10% of their compressed air through leaks, usually from loose pipe fittings, valve packing, shut off valves, worn out filters-regulators-lubricators, quick couplers, and unused air tools. A 1/16" leak can waste 6.5 cfm, and in addition to wasting compressor horsepower, will cost @ \$8.00 per month. The hundreds of leaks in many industrial air systems can represent a tremendous energy waste.</p> <p>13. Be careful to size compressor capacity fairly closely to load, since a compressor's efficiency is highest at full load.</p> <p>14. Consider the installation of several smaller compressors rather than one large unit. Sequential operation will enable each compressor to operate at full load.</p> <p>15. Prohibit all use of compressed air operated fans or compressed air hoses for personal cooling.</p> <p>16. Remember that it requires about 1 horsepower to produce 5 CFM @ 100 PSI while a 1 horsepower vane type air motor requires about 25 CFM @ 90 PSI. Investigate replacing high usage air motors with electric motors where practical.</p> <p>17. Consider using solenoid valves to cycle punch press blow off nozzles for only a short interval. Many blow off nozzles have a 1/8" orifice and, if operated continuously, will consume about 25 CFM @ 100 PSI (the equivalent of 5 HP compressor).</p> <p>18. Consider reducing the operating speed/pressure on air operated paint pumps and paint agitators during off-shift hours. Depending on pigmentation and metallic content it may even be possible to stop all agitation or circulation of some enamels or lacquers during off hours.</p> <p>19. In addition to poor partial load mechanical efficiency, induction type compressor motors have extremely poor power factors at reduced outputs. For instance, a 250 HP induction motor has a .87 PF at full load and a .55 PF at 1/4 load. Significant low load operation can drastically raise utility power factor charges.</p> <p>20. For highest efficiency, be sure air tools are kept in good repair and are not excessively worn. For instance, a sand blast nozzle worn from 5/16" to a new diameter of 3/8" would consume an additional 65-70 CFM.</p> <p>21. Minimize low load compressor operation. If air demand is less than 50% of compressor capacity, consider converting smaller compressors from constant speed operation to start/stop operation.</p> <p>22. Install timers on desiccant type compressed air dryers to match dryer recharging cycles to actual system requirements.</p> <p>23. Match compressor operation to building hours. A time switch can permit close control of compressor hours and permit shut down of high unloaded horsepower compressors during meal breaks or shift changes.</p>			

Welding Operations

- 1. Investigate converting heating equipment fuel from acetylene, natural gas, or propane to methylacetylene propadiene, stabilized (MAPP). This gas may result in the improved performance, higher cutting speeds and reduced oxygen consumption.
- 2. If product design is applicable, consider utilizing seam welding (RSEW) instead of coated electrode metal arc welding (SMAW), metallic inert-gas welding (GMAW), or submerged arc welding (SAW). Since high frequency seam welding only heats the actual welding zone, distortion is minimized. The process is also less energy intensive than most other applicable welding processes.
- 3. Consider utilizing electronic precipitators to "scrub" welding exhaust fumes and thereby eliminate building exhaust with its attendant heat loss.
- 4. Install solenoid valves on welder or water cooled torch supply lines to limit cooling water flow to actual welder operating periods.
- 5. Consider the installation of smoke detectors to control welding exhaust fans.
- 6. Investigate inertia welding for uniform tubular or solid sections and similar shapes. Inertia welding can often replace alternative welding methods with their related preparatory machining operation.
- 7. Investigate using bag type dust collectors/filters to reduce building exhaust.
- 8. If welding shop workload varies widely, investigate ordering any new transformer type welders with built-in power factor correcting capacitors.
- 9. If oxy-acetylene welding/cutting torches are frequently used throughout the day, consider installing weight actuated automatic torch valves. This should help insure that an unused torch is turned off when it is hung up.
- 10. Investigate the installation of automatic cutting torches, which normally operate at maximum speed, thus yielding maximum cutting for minimum gas consumption. Their cutting speed and accuracy can often replace more energy intensive alternative manufacturing methods.
- 11. Be sure gas welding equipment connections and hoses are tight. Leaks both waste expensive gas and are fire hazards.
- 12. Investigate using high frequency induction heating for brazing operations instead of hand-held torch or a furnace.
- 13. Consider operating automatic cutting torches on natural gas or propane instead of acetylene. Acetylene has a higher flame temperature than normally required for steel cutting.
- 14. Consider using hot air instead of direct gas flame soldering torches. Since hot air is supplied at lower temperatures, it conserves energy and improves product appearance, as well as reducing fire hazards.
- 15. Replace continuous pilot lights for gas welding torches with conventional flint lighters.

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<p>— 16. Be careful to avoid over-welding, either during design or manufacture.</p> <p>— 17. Use flame gouging instead of chipping hammers to remove tack welds, full welds, defects, blow holes, or sand inclusions.</p> <p>— 18. Consider using flame deseaming or scarfing instead of chipping hammers to remove cracks, seams, scabs, and crowsfeet. Hot scarfing can clean up forgings without the cooling and reheating required by chipping.</p> <p>— 19. In general, transformer type arc welders are more energy efficient than motor-generator welders. At full rated load, transformer type welders will consume slightly less power than a comparable motor-generator welder. At partial or no load, however, motor generator efficiency and power factor drop appreciably.</p> <p>— 20. Motor generator welders are valuable where ripple-free DC is required from single phase power. A transformer-rectifier welder cannot normally deliver well filtered DC from single phase power.</p> <p>— 21. Investigate "stack cutting" with automatic cutting torches. In many cases, a thicker cut uses proportionately less oxygen per piece than a thinner cut. Cutting accuracy is a maximum below 2" total thickness and gradually deteriorates until the normal maximum cutting thickness of 6" is attained.</p> <p>— 22. Shut down transformer type and motor-generator arc welders when not in use and during breaks and lunch. Savings will be minimal with transformer type welders but will become increasingly significant when motor-generator welders are stopped.</p> <p>— 23. Be sure unused automatic torches are turned off when not in use. Avoid excessive idle time.</p> <p>Process and Manufacturing Operations</p> <p>— 1. Evaluate all machine tool purchases carefully for operating efficiency. In some cases, an alternative manufacturing method may result in lower energy usage per piece.</p> <p>— 2. Consider installing electrostatic precipitators to minimize dust or particle exhaust, such as from welding operations.</p> <p>— 3. Investigate installing smoke detectors to operate exhaust fans.</p> <p>— 4. Interlock process ventilation equipment with the equipment it serves.</p> <p>— 5. Replace simplex or duplex steam pumps with motor driven pumps where feasible.</p> <p>— 6. Install timers on punch presses, press brakes, and hydraulic presses to shut down equipment if left idling for more than 10-12 minutes.</p> <p>— 7. Install solenoid valves on all machine air supply lines to limit air use to machine operating periods.</p> <p>— 8. Investigate using mechanical methods, such as a cam or solenoid to eject punch press parts instead of using compressed air.</p> <p>— 9. Install either automatic doors or insulated flaps on conveyor type heat treating ovens to reduce heat loss.</p>			

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<p>__10. Install solenoid valves on all water cooled equipment water lines to minimize water leakage.</p> <p>__11. Redesign processes to eliminate process exhaust ventilation.</p> <p>__12. Investigate the installation of reflecting shielding or thermal barriers around heat treating equipment to minimize cooling load on adjacent areas, particularly in metallurgical laboratories.</p> <p>__13. All water pumping equipment will have to operate at less than full design flow, consider the installation of variable speed pumps to minimize reduced flow power consumption.</p> <p>__14. Avoid severely oversizing production equipment. An oversized tool is normally heavier and requires more power than a smaller, correctly sized tool.</p> <p>__15. Operate air tools on correct pressure. Most air tools are designed to operate on 90 PSI. Tool operation on lower pressures reduces output, while only a 10 pound pressure increase results in a 14% tool life expectancy reduction.</p> <p>__16. Meter unusual gas or process chemical requirements. "Billing" a department for actual consumption can often result in phenomenal consumption reductions.</p> <p>__17. Modify product test or analysis procedures to avoid high energy consumption tests. For instance, minimize test time on engine operated equipment.</p> <p>__18. Investigate the feasibility of operating production machinery at 100% load for one shift rather than at partial load for two shifts. For instance, careful scheduling of vapor degreaser operation may permit full load operation for fewer hours.</p> <p>__19. Attempt to reduce machine idle time as much as feasible to maintain high power factors.</p> <p>__20. Assign specific plant personnel to be sure all production equipment is shut down after shift and during breaks and lunch.</p> <p>__21. Operate melt furnace exhausts only during furnace charging or fluxing if feasible.</p> <p>__22. Shut down process ventilation, building exhaust, and dust collection during breaks and lunch.</p> <p>__23. If heat treating ovens are not required for immediate use, energy can be saved by reverting to a reduced temperature condition. Investigate constructing a cool down/reheat time chart for various furnace temperature. This will enable operating personnel to easily reduce furnace temperatures and still be able to have the furnace up to heat by the desired time.</p> <p>__24. Consider operating heat treating ovens 24 hours/day to make maximum usage of energy.</p> <p>__25. Use fixed cycle times for heat treating/an-nealing operations. Many actual oven times are far longer than actually required, with a resulting energy waste.</p> <p>__26. Operate chip conveyors only when needed, not continuously.</p>			



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27. Avoid partial heat treating furnace loads.			
28. Shift or combine operations for both reduced building hours and improved machine utilization.			
29. Minimize leaks and overflow from heated process tanks.			
Material Handling and Transportation Systems			
1. Install "bump through" doors in fork lift areas to reduce open door time.			
2. Install a flexible covering, such as rubber or canvas strip, over scrap conveyor openings in building walls.			
3. Shrouds should be used in all dock doors when possible. Investigate using air curtain fans if shrouds are not available.			
4. Investigate installation of "air pallets". In some cases, they can offer energy reductions compared to lift trucks, particularly where an oddly shaped work piece must be moved short distances at slow speeds.			
5. Be sure fork lift air cleaners are clean. Some high dust locations may require centrifugal pre-cleaners to prolong filter element life.			
6. Be sure to purchase fork lift fuel that meets the manufacturers standards. Bargain fuel can actually reduce operating efficiency.			
7. In a large operation, consider the installation of two-way radio equipment on material handling equipment to reduce the number of empty return trips. Try to schedule several moves for fork lifts in an area to maximize productivity.			
8. Consider purchasing diesel fueled fork lifts. Their reduced fuel consumption and lower maintenance should result in substantial savings over gasoline or propane lifts.			
9. Investigate replacing internal combustion fork lifts with electric fork lifts. In many cases, operating costs (and energy consumption) will be lower. In some cases maintenance costs may drop up to 30%. Electric trucks also have lower downtime, are non-polluting, and are quieter.			
10. Consider installing electrical hoists rather than air operated hoists since a "1 horsepower" air hoist requires about 5 compressor horsepower, while a "1 horsepower" electric hoist requires only 1 horsepower.			
11. Replace old, out-moded (and inefficient) motor-generator electric fork lift battery chargers with new, solid state, power factor corrected high efficiency battery chargers.			
12. Avoid pushing loads. Though this only wastes fuel and wears clutches with an engine operated truck, it can severely damage a battery operated lift truck's drive motor.			
13. Install overspeed governors on all internal combustion material handling equipment, particularly fork lifts, to eliminate employee hot rodding.			
14. Investigate fork lift records or contact manufacturers to discover the best fork lift fuel consumption. Log all machine fuel to determine operator errors or machine deterioration.			

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| <p>15. Be careful not to overfill fork lift fuel tanks. Spilled gasoline or diesel fuel or vented LPG is both wasteful and hazardous.</p> <p>16. If a light load has to be moved a short distance, use a hand truck rather than a fork lift. Be sure fork lifts are used for material handling, not personal transportation.</p> <p>17. Be sure pneumatic fork lift tires are properly inflated. Underinflation both damages tires and wastes fuel.</p> <p>18. Avoid using a far larger fork lift than required. For instance, use a 2000 pound lift to maneuver oil barrels rather than a 6000 pound lift.</p> <p>19. Avoid excessive fork lift idling. Start a lift only when there is work to be done - and stop it as soon as it is completed.</p> <p>20. Avoid making a habit of using a drastically oversized crane for a drastically undersized load. If a machine frequently requires a crane to load small work pieces, consider installing a small jib crane with an electric hoist. This both frees up the main crane for heavier jobs and saves energy.</p> <p>21. Install automatic timers to shut down crane motor generators if no crane moves are made within ten minutes.</p> | | | |

Paint Line Operations

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| <p>1. Consider use of airless spray instead of air spray paint application. While it requires about 9.5 HP to atomize 1 GPM using air spray, it only requires about 1.3 HP to atomize 1 GPM using airless spray. Airless spray is particularly suited to large, heavy work pieces that must be painted with one coat, in place, such as heavy construction equipment, barges, structural steel, or railroad cars.</p> <p>2. Since natural gas is a decreasing resource, investigate the applicability of ultra-violet cured metal finishes to your product. Frequently, product redesign may enable the use of ultra-violet post coating or may permit using pre-coated coil stock. In many cases, coil coating uses only about 20% of the energy required for post painting.</p> <p>3. Consider installation of direct fired paint ovens instead of indirect fired. The heat transfer coefficient for direct fired is about 97% versus 60% for indirect fired, with comparable differences in fuel consumption.</p> <p>4. Investigate conversion to water base painting materials. Water base usually cuts energy consumption by reducing spray booth air flow, oven exhaust, air makeup requirements, and oven times. In some cases, finishing lines have reduced total natural gas consumption up to 45%.</p> <p>5. Research is currently being done to develop low temperature cure and air dry waterbase coatings. Current future forecasts often predict water base may account for up to 60% of the industrial finishing market by 1985.</p> <p>6. Consider utilizing gas fired washer combustion products to provide heat for dry off oven. This would be particularly applicable to direct fired washers.</p> | | | |
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- 7. If your product configuration is applicable, consider converting to a high intensity infra-red curing which uses as little as 10% of the energy required for a comparable gas fired oven.
- 8. Investigate converting paint ovens to the "Raw Oven Exhaust Recycle Process". This system returns part of the oven exhaust back to the oven after passing through an incinerator.
- 9. Investigate conversion to airless paint drying from conventional oven baking. This system holds oven oxygen content to as low as 1%, with resulting reductions in oven exhaust and gas requirements.
- 10. Reduce spray booth/makeup air temperature to 65° - 68°.
- 11. Investigate installing electric ovens instead of gas or oil fired. Higher operating costs are somewhat reduced by better temperature control, constant one-fuel operation, and more readily controllable oven atmosphere.
- 12. Consider insulating the entire paint line parts washer to reduce heat loss. Some plant operators estimate they have achieved up to 20% fuel reduction in metal pretreatment operations after insulating parts washers.
- 13. If insulating the entire washer is not feasible, investigate insulating the heated portion of the washer.
- 14. Consider additional paint oven wall insulation. Doubling the present thickness (usually only 2") will cut wall losses in half. Since most paint oven heat is lost through oven roofs, this portion in particular should be well insulated.
- 15. Consider utilizing ambient temperature solvent flash off if possible. In many cases, a slightly longer or slower conveyor may be all that is required.
- 16. Considerable heat is lost through oven "air seals", which are generally ineffective. Consider installation of bottom entry/exit oven, which better retain heated air within the oven.
- 17. Consider installations of oil fired paint ovens instead of gas fired. New oven technology can minimize paint discoloration and soot problems if a light, low sulfur (1%), oil is used.
- 18. Consider heat recovery equipment, such as "heat pipes", in spray booth and bake oven stacks. If heat recovery equipment is used, a regular maintenance program is required to minimize heat losses caused by paint residue build up.
- 19. Consider switching to low or ambient temperature parts washer cleaners and phosphating compounds. For instance, iron phosphates are now being successfully used at 100-120°F. in some applications.
- 20. Investigate staging spray booth air flow. If painters work only in the first section, with automatic spray equipment in the remaining zones, the booth air can flow into the first zone, and be exhausted to the other zones. In many cases, solvent concentration in the final zone would still be below the 25% LFL limit.

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<p>21. Replacing manual spray with automatic paint spraying machinery may permit a reduction in spray booth air velocity with a resultant make up air reduction. Material flammability and toxicity must be investigated to determine if any reductions are feasible. This normally requires approval from insurance inspectors, fire inspectors, O.S.H.A., and any other applicable agencies.</p> <p>22. Investigate using process steam condensate as heat source for paint line parts washer tanks.</p> <p>23. Use a fixed orifice rather than an adjustable valve to meter water into process or paint line constant overflow tanks for minimum flow.</p> <p>24. Check booth velocity carefully to avoid over exhausting. Consider using electrostatic spray since this usually permits a reduction of booth velocity of about 40%.</p> <p>25. Investigate interlocking paint line conveyors with parts washers and bake ovens.</p> <p>26. Investigate the feasibility of operating fume incinerators at reduced temperatures.</p> <p>27. If paint line or process exhausts include extremely high solvent concentrations, investigate recovering and re-refining these otherwise wasted solvents. In some cases, solvents have been reclaimed at an energy cost 1/5 - 1/6 the price of new solvent.</p> <p>28. Be sure plant is not occasionally under negative pressure. Negative pressure can starve gas burners resulting in a fuel rich flame with excess CO. Negative pressure also results in increased air infusion through walls and windows, with resulting cold drafts and worker complaints.</p> <p>29. Be sure all stages in a process are really necessary. In some applications, washer stages may be eliminated or partially shut down, as may dry off ovens.</p> <p>30. If batch ovens are used, maximize loading and optimize working hours for highest energy efficiency. Similarly, minimize warm up time as much as possible.</p> <p>31. Because solvents are increasingly scarce and expensive, consider filtering, distilling, or otherwise recycling solvent.</p> <p>32. It may be possible to improve paint oven heat transfer by increasing circulating air velocities or volume and by utilizing heating system radiant energy. Improved heat transfer may permit increased travel speeds with resulting increases in production with little or no increase in fuel requirements.</p> <p>33. Sequentially shut down ovens at end of shift or production run.</p> <p>34. Attempt to schedule all paint line operations for one shift if feasible.</p> <p>35. Be sure all gas immersion tubes used for liquid heating are clean (both interior and exterior) for best heat transfer.</p> <p>36. Be sure all air filters are kept clean.</p> <p>37. Change paint line conveyor speed and hook configuration as required with product changes to maximize productivity and minimize oven idle time.</p> <p>38. Reduce conveyor speed when parts are not flowing through wash or bake ovens.</p>			